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**Work Plan for a
Treatability Study in Support of
Remediation by Natural Attenuation at Building 1212**



**Fairchild Air Force Base
Spokane, Washington**

Prepared For

**Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base
San Antonio, Texas**

and

**92 CES/CEVC
Fairchild Air Force Base
Spokane, Washington**

May 1996



**PARSONS
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WORK PLAN FOR A TREATABILITY STUDY
IN SUPPORT OF REMEDIATION BY NATURAL ATTENUATION AT
BUILDING 1212
FAIRCHILD AIR FORCE BASE, WASHINGTON

for

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

and

92 CES/CEVC
FAIRCHILD AIR FORCE BASE
SPOKANE, WASHINGTON

May 1996

Prepared
by

Parsons Engineering Science, Inc.
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AQM01-01-0310

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SECTION 1

INTRODUCTION

This work plan, prepared by Parsons Engineering Science, Inc. (Parsons ES), formerly Engineering-Science, Inc. (ES), presents the scope of work required for the collection of data necessary to conduct a treatability study (TS) for remediation of groundwater contaminated with petroleum hydrocarbons at Building 1212 located at Fairchild Air Force Base (AFB), 12 miles west of Spokane, Washington (the Base). Hydrogeological and groundwater chemical data collected under this program can be used to evaluate various remedial options; however, this work plan is oriented toward the collection of hydrogeological data to be used as input into groundwater flow and solute transport models in support of remediation by natural attenuation (RNA) with long-term monitoring (LTM) for restoration of groundwater contaminated with benzene, toluene, ethylbenzene, and xylene (BTEX).

As used in this report, RNA refers to a management strategy that relies on natural attenuation mechanisms to remediate contaminants dissolved in groundwater and to control receptor exposure risks associated with contaminants in the subsurface. The United States Environmental Protection Agency (USEPA) Office of Research and Development (ORD) and Office of Solid Waste and Emergency Response (OSWER) define natural attenuation as:

The biodegradation, dispersion, sorption, volatilization, and/or chemical and biochemical stabilization of contaminants to effectively reduce contaminant toxicity, mobility, or volume to levels that are protective of human health and the ecosystem.

As suggested by this definition, mechanisms for natural attenuation of BTEX include advection, dispersion, dilution from recharge, sorption, volatilization, and biodegradation. Of these processes, biodegradation is the only mechanism working to transform contaminants into innocuous byproducts. Contaminant destruction occurs through biodegradation when indigenous microorganisms work to bring about a reduction in the total mass of contamination in the subsurface without the addition of nutrients. Patterns and rates of natural attenuation can vary markedly from site to site depending on governing physical and chemical processes.

RNA is advantageous for the following reasons:

- Contaminants are transformed to innocuous byproducts (e.g., carbon dioxide and water), not just transferred to another phase or location within the environment;
- Current pump-and-treat technologies are energy-intensive and generally not as effective in reducing residual contamination;
- The process is nonintrusive and allows continuing use of infrastructure during remediation;
- Current engineered remedial technologies may pose a greater risk to potential receptors than RNA (e.g., contaminants may be transferred into another medium during remediation activities); and
- RNA is far less costly than conventional, engineered remedial technologies.

As part of the TS, the contaminant fate and transport modeling effort has three primary objectives: 1) predict the future extent and concentration of dissolved contaminant plumes by modeling the effects of advection, dispersion, sorption, and biodegradation over time and distance; 2) assess the possible exposure of potential downgradient receptors to contaminant concentrations that exceed levels intended to be protective of human health and the environment; and 3) to provide technical support for selection of RNA as the best remedial alternative at regulatory negotiations, as appropriate. The modeling efforts for Building 1212 at Fairchild AFB will involve completion of several tasks, which are described in the following sections.

This work plan was developed following discussions with representatives from the Air Force Center for Environmental Excellence (AFCEE), 92nd Civil Engineering Squadron--Environmental (92 CES/CEVC), and on a review of existing site characterization data. All field work will follow the health and safety procedures presented in the program *Health and Safety Plan for Bioplume II Modeling Initiative* (ES, 1993), and the site-specific addendum to the program Health and Safety Plan. This work plan was prepared for AFCEE and 92 CES/CEVC.

1.1 SCOPE OF CURRENT WORK PLAN

This project is part of a larger, broad-based initiative being conducted by AFCEE in conjunction with USEPA National Risk Management Research Laboratory (NRMRL), formerly known as the Robert S. Kerr Environmental Research Laboratory (RSKERL), and Parsons ES. The intent of the RNA demonstration program is to develop a systematic process for scientifically investigating and documenting natural subsurface chemical attenuation processes that can be factored into overall site remediation plans. For this reason, the work described in this work plan is directed toward the collection of data in support of demonstrating the effectiveness of RNA for fuel-contaminated groundwater. Data required to develop alternative remedial strategies, should RNA prove not to be a viable remedial option at this facility, also will be collected under this program. A secondary goal of this multi-site initiative is to provide a database from

multiple sites that demonstrates that natural processes of contaminant degradation often can reduce contaminant concentrations in groundwater to below acceptable cleanup standards before potential receptor exposure pathways are completed.

The specific objective for the demonstration at Building 1212 is to provide solid evidence of RNA of petroleum hydrocarbons dissolved in groundwater so that this information can be used by the Base and its prime environmental contractor(s) to develop an effective groundwater remediation strategy. As a result, this demonstration is not necessarily intended to fulfill specific federal or state requirements regarding site assessments, remedial action plans (RAPs), or other such mandated investigations and reports.

This work plan describes the site characterization activities to be performed by personnel from Parsons ES and the Subsurface Protection and Remediation Division of the NRMRL in support of the TS. Field activities will be performed to determine the effectiveness of RNA in remediating the potential dissolved BTEX plume at Building 1212. The data collected during the TS will be used along with data from previous investigations to characterize contaminant and geochemical patterns at the site, and for use in the groundwater flow and solute transport models to make predictions of the future concentrations and extent of contamination.

Site characterization activities in support of the TS will include: 1) determination of preferential contaminant migration and potential receptor exposure pathways; 2) split-spoon soil sample collection using a hollow-stem auger (HSA) drill rig; 3) groundwater monitoring well installation using an HSA drill rig; 4) groundwater sample collection; 5) soil and groundwater sample analysis; and 6) aquifer testing. The materials and methodologies to accomplish these activities are described herein. Previously reported site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the groundwater flow and solute transport models. Where site-specific data are not available, conservative values for the types of aquifer materials present at the site will be obtained from widely accepted published literature and used for model input. Sensitivity analyses will be conducted for the parameters that are known to have the greatest influence on the model results, and where possible, the model will be calibrated using historical site data. Upon completion of the modeling, Parsons ES will provide technical assistance at regulatory negotiations to support RNA if the results of the modeling indicate that this approach is warranted. If it is shown that RNA is not the most appropriate remedial option, Parsons ES will recommend the most appropriate groundwater remedial technology on the basis of available data.

This work plan consists of six sections, including this introduction. Section 2 presents a review of available, previously reported, site-specific data and a preliminary conceptual model for the site. Section 3 describes the proposed sampling strategy and procedures to be used for the collection of additional site characterization data. Section 4 describes the remedial option evaluation procedure and TS report format. Section 5

describes the quality assurance/quality control (QA/QC) measures to be used during this project. Section 6 contains the references used in preparing this document. There is one appendix to this work plan. Appendix A contains a listing of containers, preservatives, packaging, and shipping requirements for soil and groundwater samples.

1.2 BACKGROUND

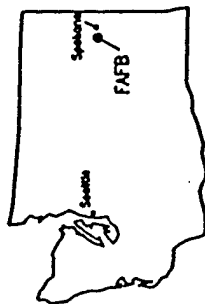
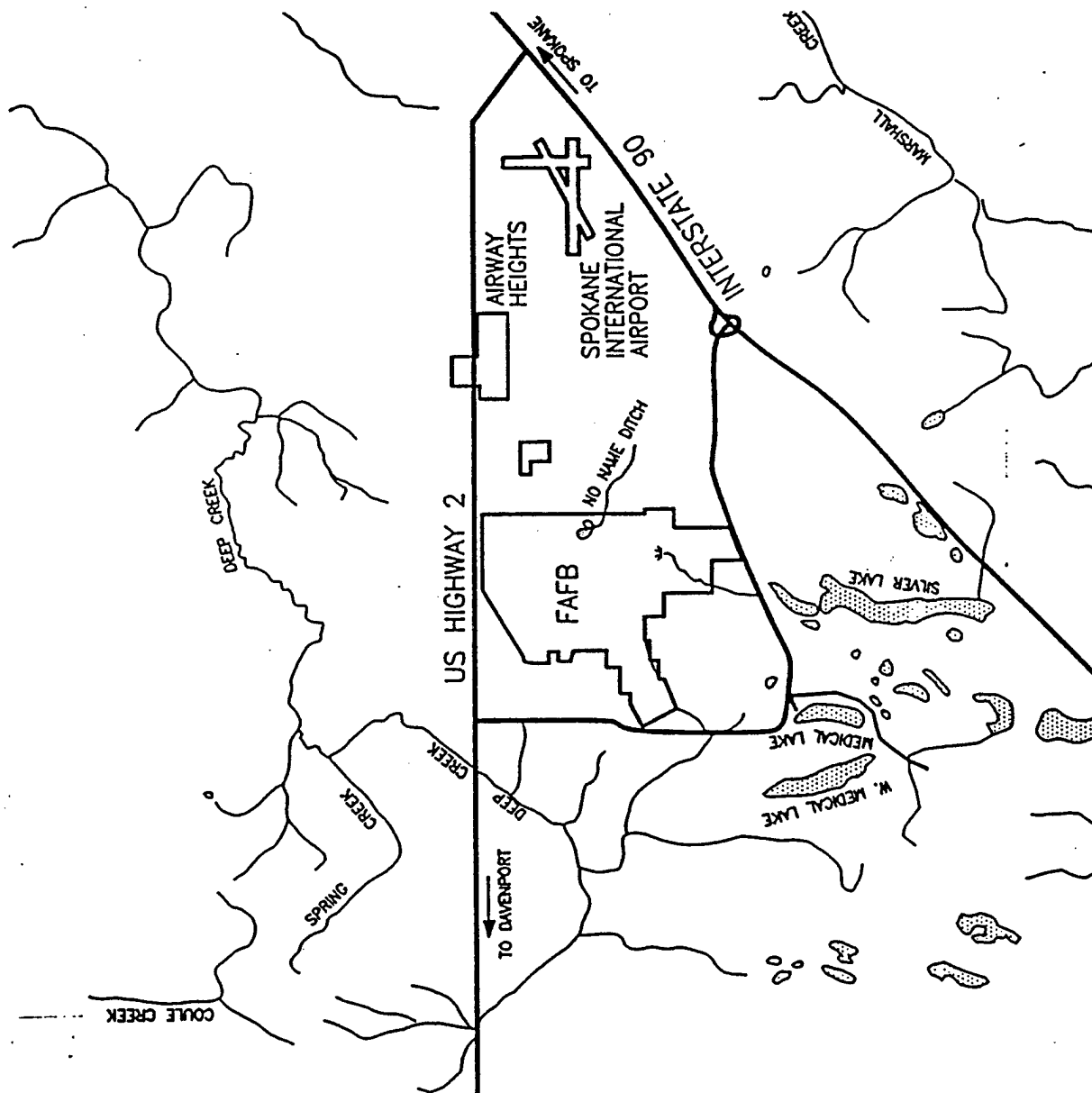
Fairchild AFB occupies an area of approximately 4,300 acres 12 miles west of Spokane, Washington (Figure 1.1). The Base is divided roughly in half by the main northeast/southwest runway (Figure 1.2). Aircraft operational facilities, approximately 1,600 Base housing units, an elementary school, a hospital, and support facilities for the tenants housed on-Base lie north of the runway. The air traffic control tower, weapons storage area, and survival training school lie to the south of the runway [Halliburton NUS (HNUS), 1993].

The Base was established in 1942 as an Army repair depot and was transferred to the Strategic Air Command (SAC) in 1947. In 1992, Base control was transferred to the Air Combat Command (ACC). Currently, the Base is operated by the Air Mobility Command (AMC) and serves as host to the 92nd Air Refueling Wing. The Base also is the current home of the 141st Air Refueling Wing of the Washington Air National Guard (WANG), aircraft operational facilities, a weapons storage area, and a survival training school. Base operations employ approximately 5,000 civilian and military personnel (ES, 1994).

Building 1212 is the Transportation Resistance Training Facility at AFB. Building 1212 is located south of the runway along Thorpe Road, southwest of the sewage disposal facility (Figure 1.2). The site is covered by a broad expanse of asphalt, pavement, and concrete, with the exception of a small area between the lot and Thorpe Road that is landscaped with grasses. Currently, Building 1212 is used as a gas station for the training facility.

On October 4 and 5, 1995, two 3,000-gallon gasoline underground storage tanks (USTs) were removed from beneath the asphalt/pavement area near Building 1212 by Budinger & Associates for replacement with one 4,000 gallon tank. Prior to the removal of the gasoline USTs a heating oil tank was excavated and removed. A large stockpile of overburden from this tank excavation was left next to the excavation site (Figure 1.3). No known spills have occurred at Building 1212, but field observations made by Budinger & Associates personnel during the October 1995 UST removal effort suggest that pipes leading to and from the tanks may have leaked at an unknown time. Budinger & Associates (1995) reported severely contaminated soils surrounding some of the threaded connections from the product supply piping and dispenser piping. It also was reported that some of the welds on both tanks may have leaked at one time.

Soil contamination from the two gasoline USTs was reported between 3 to 9 feet below ground surface (bgs) in the eastern end of the removal excavation. Occurrence



Key Plan

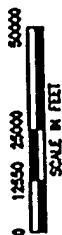


FIGURE 1.1

BASE LOCATION

Fairchild AFB, Washington



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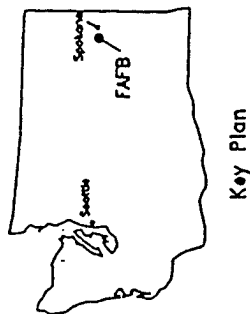
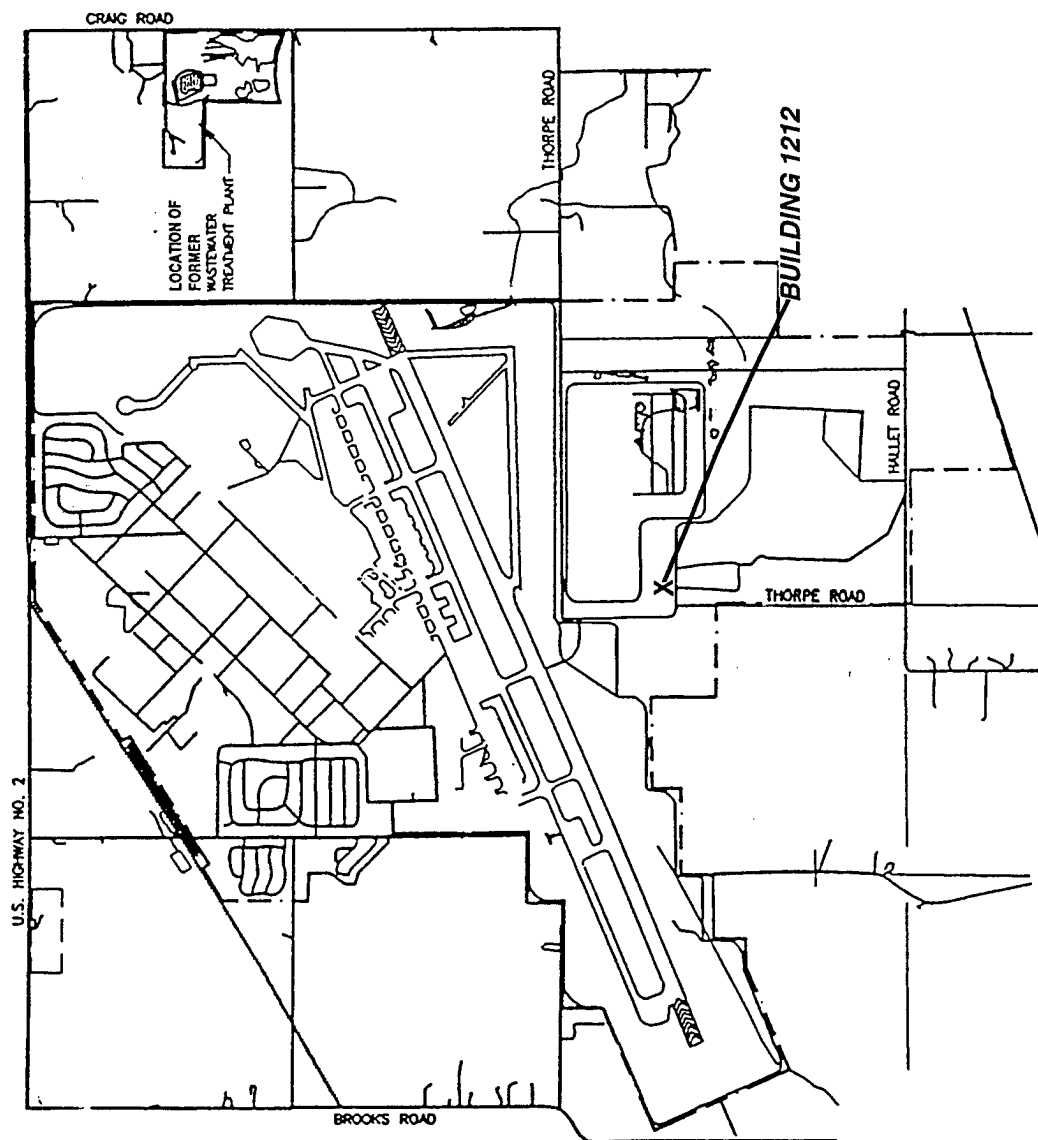


FIGURE 1.2

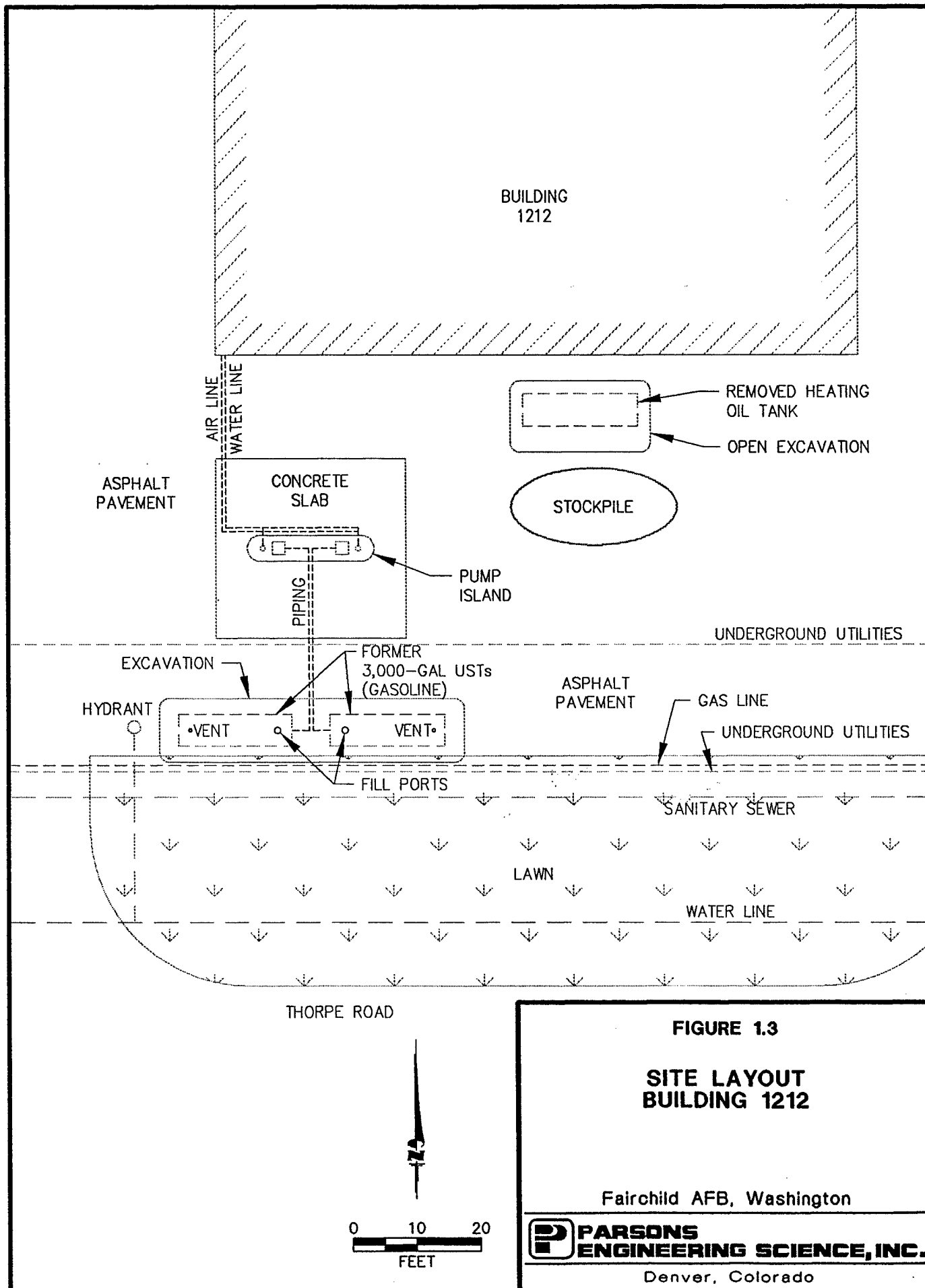
SITE LOCATION

Fairchild AFB, Washington



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and magnitude of contamination appeared variable. At the western end of the excavation some slightly contaminated soils were encountered. To date, groundwater contamination has not been confirmed at Building 1212. As a part of this TS, approximately 16 groundwater monitoring wells will be installed to confirm and define the extent of groundwater and mobile light nonaqueous-phase liquid (LNAPL) contamination at Building 1212.

SECTION 2

DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT

Previously reported site-specific data were reviewed and used to develop a preliminary conceptual site model (CSM) for the groundwater flow and contaminant transport conditions at Building 1212. The CSM guides sampling locations and selection of analytical data requirements needed to support the modeling efforts and to evaluate potential remedial approaches, including RNA. Section 2.1 presents a synopsis of available site characterization data. Section 2.2 presents the preliminary conceptual groundwater flow and contaminant transport model that was developed based on these data.

2.1 DATA REVIEW

The following sections are based upon review of data from the following sources:

- Remedial Investigation/Feasibility Study (RI/FS) Site Characterization Summary Report Priority 1 Sites Fairchild AFB [Science Applications International Corporation (SAIC), 1990];
- Installation Restoration Program (IRP) Remedial Investigation Report (HNUS, 1993);
- Long-Term Monitoring Report For Priority 1 Sites SW-1 (LF-01), PS-2 (SS-18), and PS-8 (SS-26) at Fairchild AFB, Washington (ICF Technology, Inc. (ICF), 1995); and
- Letter Report For UST Removal, Site #1212, Transport Resistance Training Facility, Fairchild AFB, Washington (Budinger & Associates, 1995).

2.1.1 Topography, Surface Hydrology, and Climate

Fairchild AFB is located within the Columbia Basin in the northeastern corner of the 55,000-square-mile Columbia Plateau Physiographic Province (ICF, 1995). The Columbia Plateau is bordered by mountains and highlands on all side. The northern edge of the Plateau gives way to the Okanogan Highlands roughly 75 miles north of Fairchild AFB, while the eastern end of the Plateau is bordered by the Rocky Mountains, approximately 75 miles east of Fairchild AFB. The Plateau extends approximately 250 miles to the south and west of the Base; the Blue Mountains border

the Plateau on the south, and the Cascade Mountains border the Plateau on the west. There is a watershed divide in the center of the Plateau that causes streams north of this divide to flow in a northerly direction, and streams south of the divide to flow in a southerly direction. The topography of the region was shaped by glacial flood waters that eroded the surface of the Columbia Plateau during the Pleistocene Epoch (approximately 22,000 years ago) (HNUS, 1993). The surface topography of the Base and surrounding region is generally flat to gently rolling grasslands sloping slightly to the east-northeast. Ground surface elevations on the Base range from 2,400 to 2,460 feet above mean sea level (msl) (Figure 2.1).

Fairchild AFB is located in the northern half of the Columbia Plateau, north of the watershed divide. All surface water drainage in this region of the Columbia Plateau generally flows to the north or northwest (Flint, 1936). The Base is approximately 7 miles west-southwest of the Spokane River, which flows through the city of Spokane [US Geologic Survey (USGS), 1973a, 1973b, 1986a, and 1986b]. Two other drainages in the vicinity of the Base are Deep Creek and Marshall Creek, located approximately 2 miles northwest and 8 miles southeast of the Base, respectively (Figure 1.1). These creeks flow northwest and join the Spokane River, which drains this region of the Plateau. Surface water on the Base is generally limited to precipitation runoff. Surface water drainage is controlled within a series of manmade ditches. Reportedly, water collected in the ditch system does not leave Base property, and surface water either infiltrates the subsurface or evaporates (HNUS, 1993). Surface runoff at Building 1212 is controlled by positive runoff-sloped pavement to the west, north and east. Stormwater is directed to the nearby lawn areas via the roads and paved lots around Building 1212.

Fairchild AFB is surrounded by semi-arid grasslands common to this area of the Columbia Basin. The Base receives approximately 16 inches of rainfall during the warm dry summers, and 40 inches of snowfall during the cool, damp winter months. The prevailing wind direction in the region is to the northeast at an average speed of 8 miles per hour (ICF, 1995). The average evapotranspiration rate for the region is reported at 12.8 inches per year (JRB Associates, 1985). Maximum infiltration rates usually occur during the early spring when snow melt runoff combines with precipitation while temperatures are still cool and evapotranspiration is low (SAIC, 1990).

2.1.2 Overview of Geology and Hydrogeology

2.1.2.1 Regional Geology and Hydrogeology

The shallow subsurface geology at Fairchild AFB is a mixture of Tertiary volcanics and Quaternary sediments consisting of eolian, glacial, fluvial, lacustrine, and catastrophic flood deposits (Figure 2.2). Flood waters from the glacial-era Missoula Lake scoured the basalt bedrock of this region of the Columbia Plateau. Coarse sediments were deposited during the early recession of flood waters, followed by finer

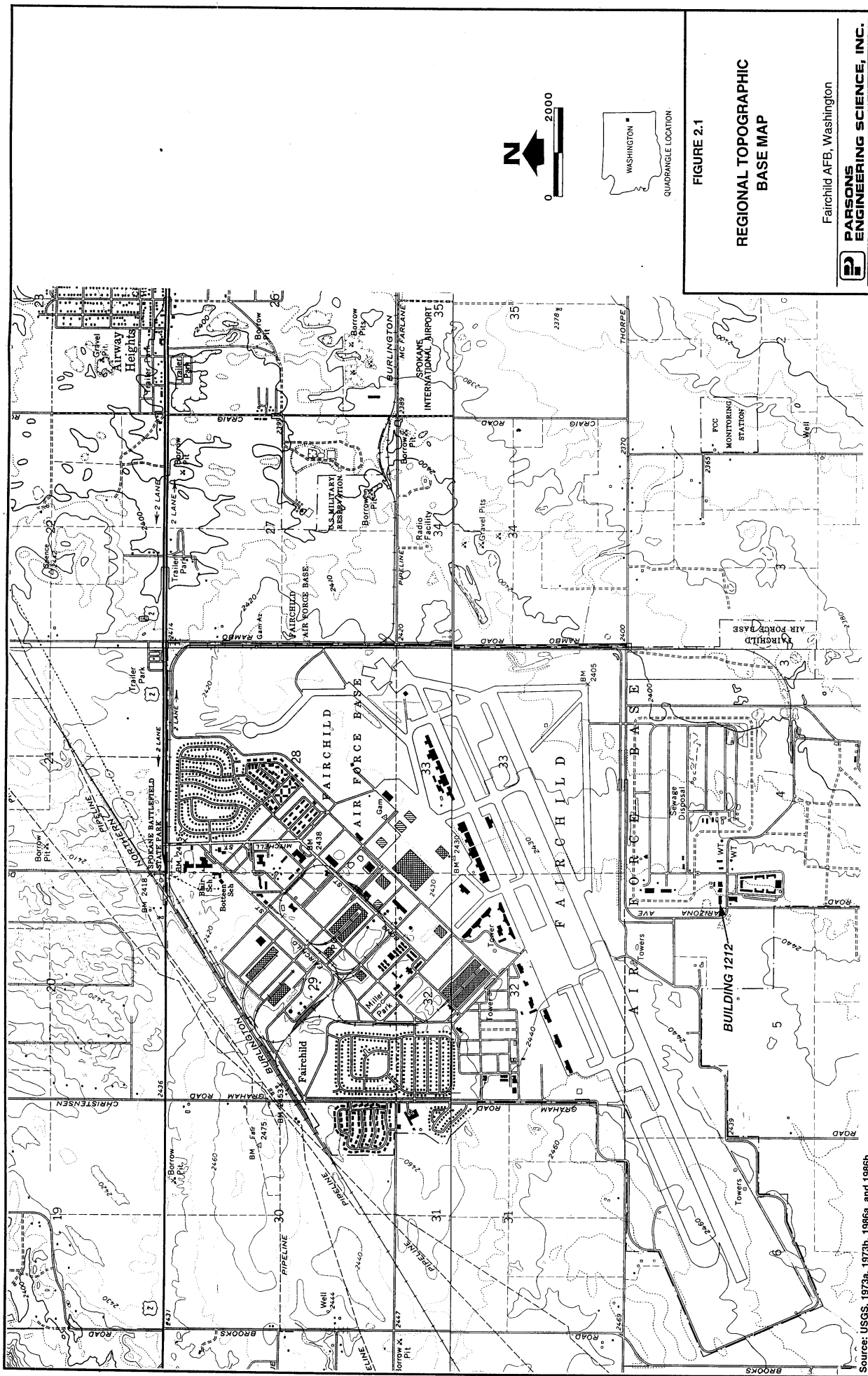
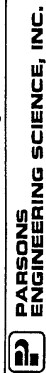


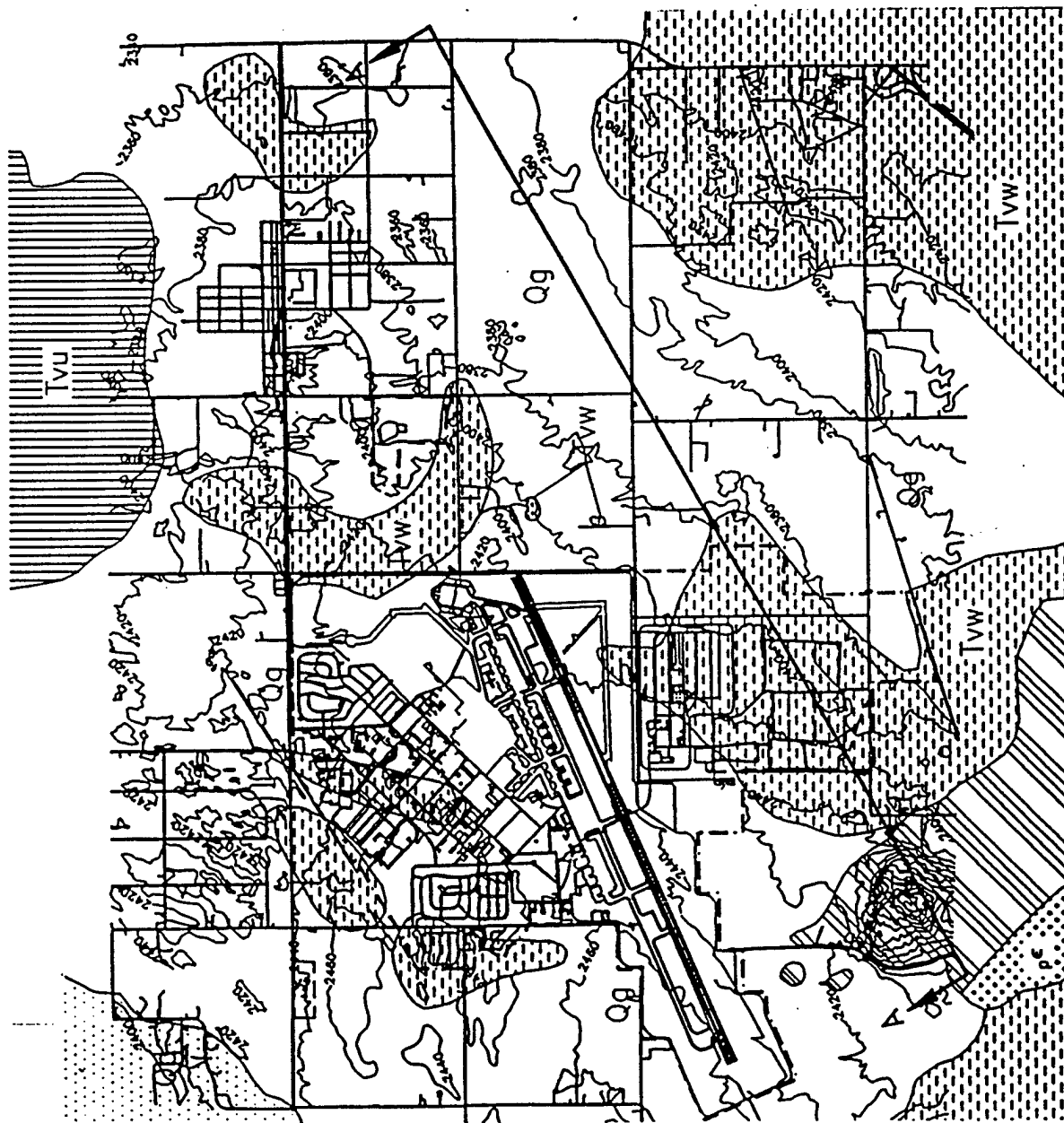
FIGURE 2.1

REGIONAL TOPOGRAPHIC BASE MAP

Fairchild AFB, Washington



Source: USGS, 1973a, 1973b, 1986a, and 1986b.



LEGEND

	EOLIAN SAND DUNES
	REWORKED GLACIAL SEDIMENTS
	GLACIAL DEPOSITS
	TERTIARY VOLCANICS WASHINGTON FORMATION (BASALT)
	TERTIARY VOLCANICS UNDEFINED (BASALT)
	TERTIARY INTRUSIVES
	PRECAMBRIAN META-SEDIMENTARY ROCKS

SURFACE TOPOGRAPHIC CONTOURS

LOCATION OF GEOLOGIC CROSS SECTION



FIGURE 2.2

SURFACE GEOLOGIC MAP AND LOCATION OF REGIONAL CROSS SECTION A-A'

Fairchild AFB, Washington



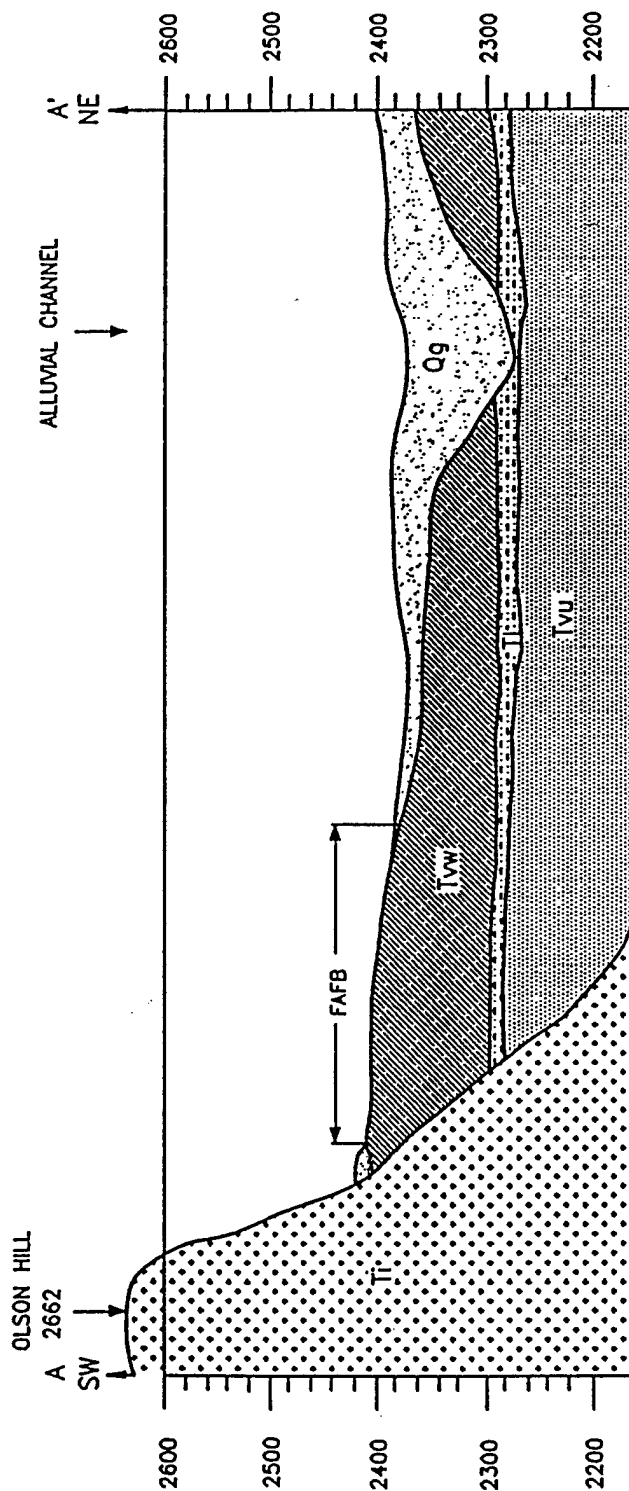
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sediments during the later stages of floodwater recession. Unconsolidated deposits in the vicinity of the Base generally consists of fine-grained sediments deposited by receding glacial flood waters. Clays and silts are intermixed with sandy silts, clays, and gravels (SAIC, 1990). In addition, loess (windblown silt) deposits are interbedded in portions of the alluvium. Unconsolidated deposits generally follow the slope of the underlying basalt bedrock (ICF, 1995).

Bedrock in the vicinity of the Base is mostly Tertiary Basalts of the Columbia River Group. Specifically, ~~basalts below Fairchild AFB~~ are of the Wanapum Formation (HNUS, 1993). The basalt flows in the region are interbedded with sedimentary clay and silt units of the of the Latah Formation. These layers were deposited when stream beds were isolated by the volcanic basalt flows (Cline, 1969). The Wanapum basalt flow below the Base appears to be divided into an upper and lower flow sequence by an interbed of the Latah Formation (Figure 2.3). The upper basalt flow is 166 feet to 193 feet thick across the Base. The surface of the upper basalt flow is vesiculated, deeply fractured, and highly weathered in places. Just east of the Base this upper basalt layer was completely eroded by the Missoula Lake flood waters. The middle section of this flow contains few vesicles and fractures; the formation becomes more massive and competent with depth. The underlying Latah Formation deposits consist of an extensive silty claystone that ranges in thickness from 8.5 to 10 feet (SAIC, 1990). Information on the geologic characteristics of the lower basalt flow is not available in the previous reports reviewed during preparation of this work plan; however, information on the lower basalt flow is not considered to be vital to the formation of the CSM for data collection in support of RNA at Building 1212.

Groundwater in the vicinity of the Base is encountered between 8 to 12 feet bgs and is found in both the unconsolidated overburden material and the underlying basalt bedrock. Groundwater flow in the overburden is through intergranular pore space, while flow in the basalt is through interconnecting fractures (HNUS, 1993). Flow across the Base is generally to the east and east-northeast, but local variations may result from local changes in bedrock topography (Figure 2.4). Groundwater in the overburden and shallow bedrock is generally unconfined, with some local semiconfined areas. The overburden and the shallow basalt are hydraulically connected by fractures, vesicles, and weathered zones. The middle region of the shallow basalt flow, which is more competent with less fracturing, acts as an aquitard. The interbedded latch claystone between the basalt flows also acts as a confining layer (HNUS, 1993).



VERTICAL EXAGGERATION = 25:1

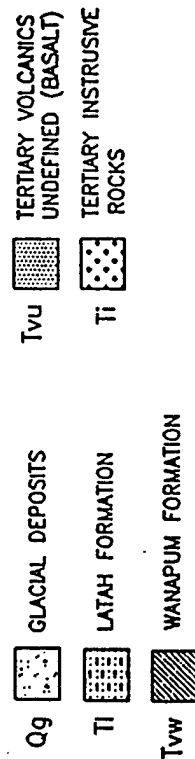


FIGURE 2.3

REGIONAL GEOLOGIC CROSS SECTION A-A'

Fairchild AFB, Washington



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

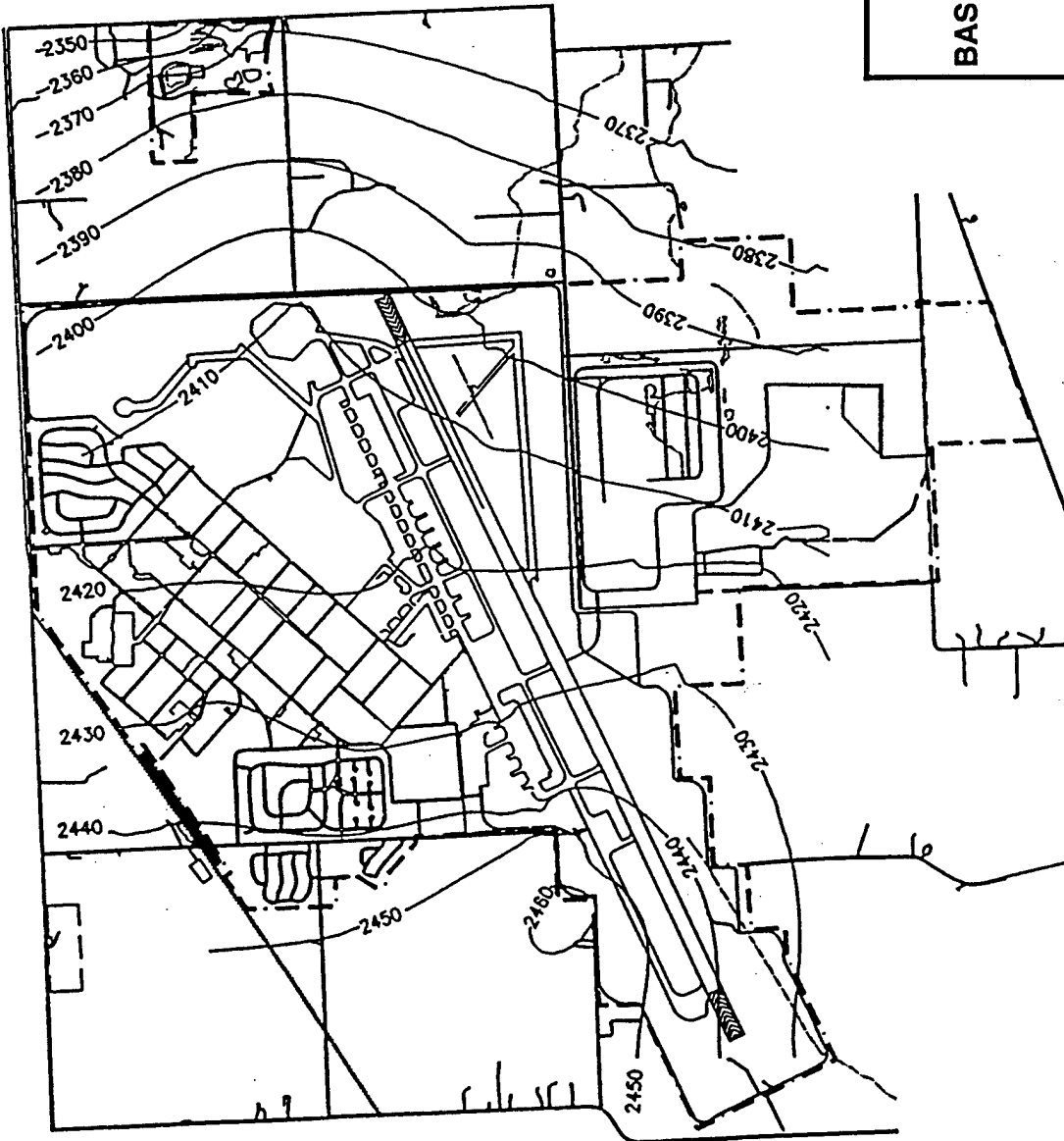


FIGURE 2.4

BASEWIDE GROUNDWATER SURFACE
ELEVATION CONTOUR MAP
APRIL 1993

Fairchild AFB, Washington

PARSONS
ENGINEERING SCIENCE, INC.

Denver, Colorado

Source: ICF Technology Inc., 1995.

Recharge of the aquifer under the Base is expected to come from upgradient flow and precipitation infiltration. Shallow groundwater in the vicinity of the Base is not known to be used as a drinking water supply. Neighborhoods to the east and northeast of the Base obtain domestic and agricultural water primarily from private wells that tap aquifers in the deeper basalt flows. The closest residential neighborhoods are roughly 6,000 feet downgradient from the site, near the eastern boundary of the Base. Base drinking water is primarily supplied from a Base-owned well field 10 miles northwest of the Base. In addition, there is a water supply well located in the southern area of the Base. This well produces water from the deep basalt aquifer and supplies roughly 10 percent of the Base's needs (HNUS, 1993).

2.1.2.2 Building 1212 Geology and Hydrology

Most of the ground surface at Building 1212 is covered by asphalt pavement except for a small lawn area just south of the building between the pavement and Thorpe Road, and a concrete slab underlying the pump island (Figure 1.3). The thicknesses of the concrete slab and the surrounding asphalt pavement are not known. Areas west, east, and north of the USTs are sloped for positive runoff.

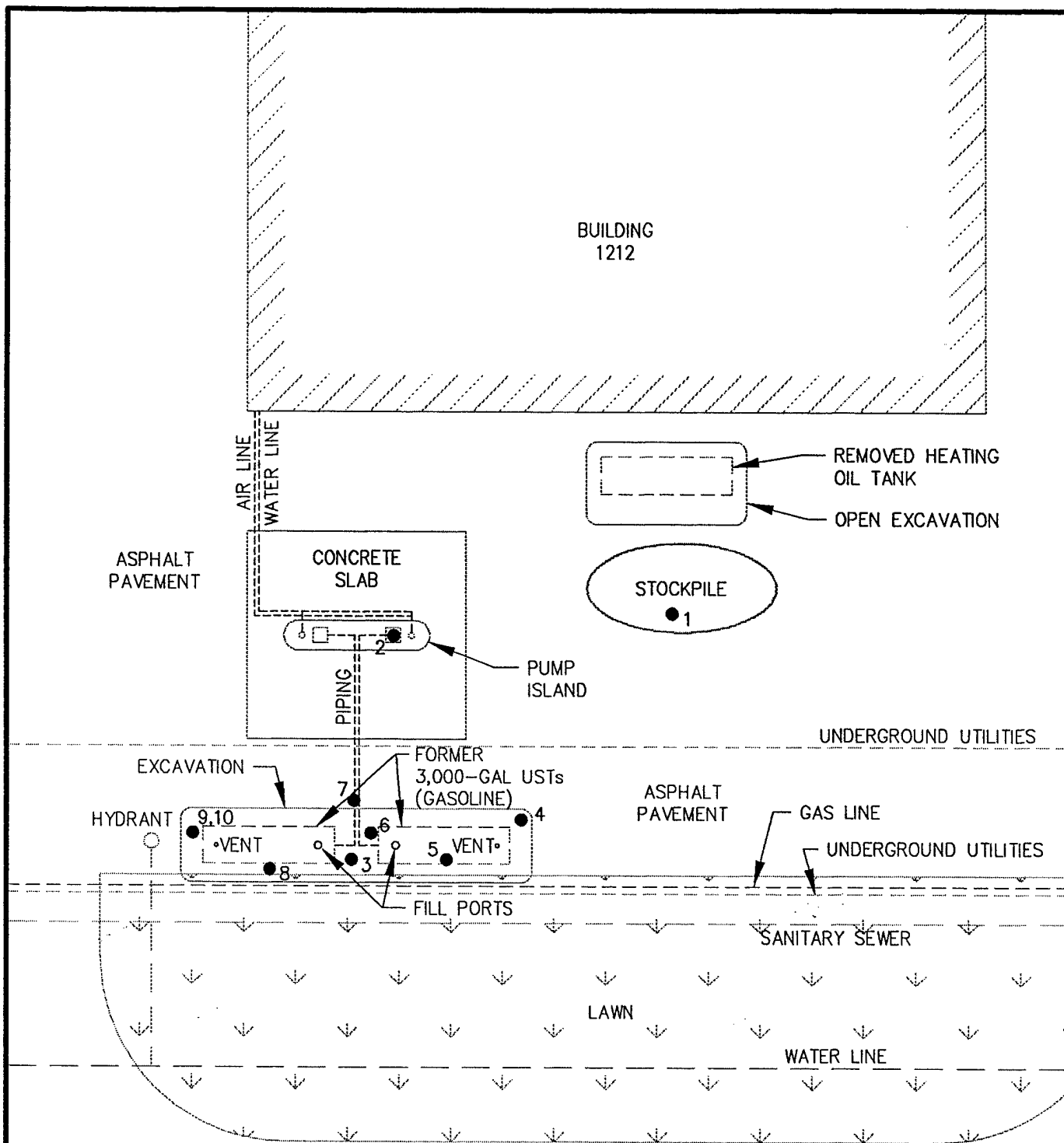
During the excavation of the gasoline USTs, field personnel noted subsurface geology and hydrogeology. The upper 2 feet of soil consists of a mixture of gravel, sand, and silt, which appears to be fill used to raise and level the site (Budinger & Associates, 1995). Soils are moderately well-graded and are considered to have slow permeabilities. Deeper soils consist of silt with a small amount of fine sand and trace amounts of clay. The soils are slightly plastic, somewhat cohesive, and considered to be slowly permeable. Occasional laminations of fine sand and/or silt also were observed during the excavation. The deeper soils are believed to be native soils that were used to backfill around the tanks during their original installation.

Shallow groundwater beneath the site is believed to flow in an easterly direction, with a gradient of approximately 0.005 foot per foot (ft/ft) at a depth of approximately 6 to 9 feet bgs. Groundwater was observed in the open heating oil tank excavation at approximately 9 feet below the paved lot surface. Saturated soils were encountered around 6 to 7 feet bgs in the gasoline USTs excavation. Free groundwater was not observed in the UST excavation, which suggests relatively low transmissivity for the shallow water table. Because soils are slowly permeable, it may take several days for water levels to stabilize after physical disturbance.

2.1.3 Summary of Analytical Data for Building 1212

2.1.3.1 Soil Sampling and Analytical Results

During the removal of the two gasoline USTs in October 1995, nine soil samples were collected from the excavation, and one soil sample was collected from the stockpile of soils from the excavation of the heating oil tank (Figure 2.5). Analytical results for these 10 soil samples are shown on Figure 2.6 and presented in Table 2.1.



LEGEND

- SOIL SAMPLING POINT

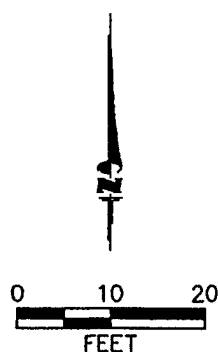


FIGURE 2.5
LOCATION OF SOIL
SAMPLES COLLECTED
DURING UST REMOVAL (1995)

Fairchild AFB, Washington

PARSONS
ENGINEERING SCIENCE, INC.

Denver, Colorado

Source: Budinger & Associates, 1995.

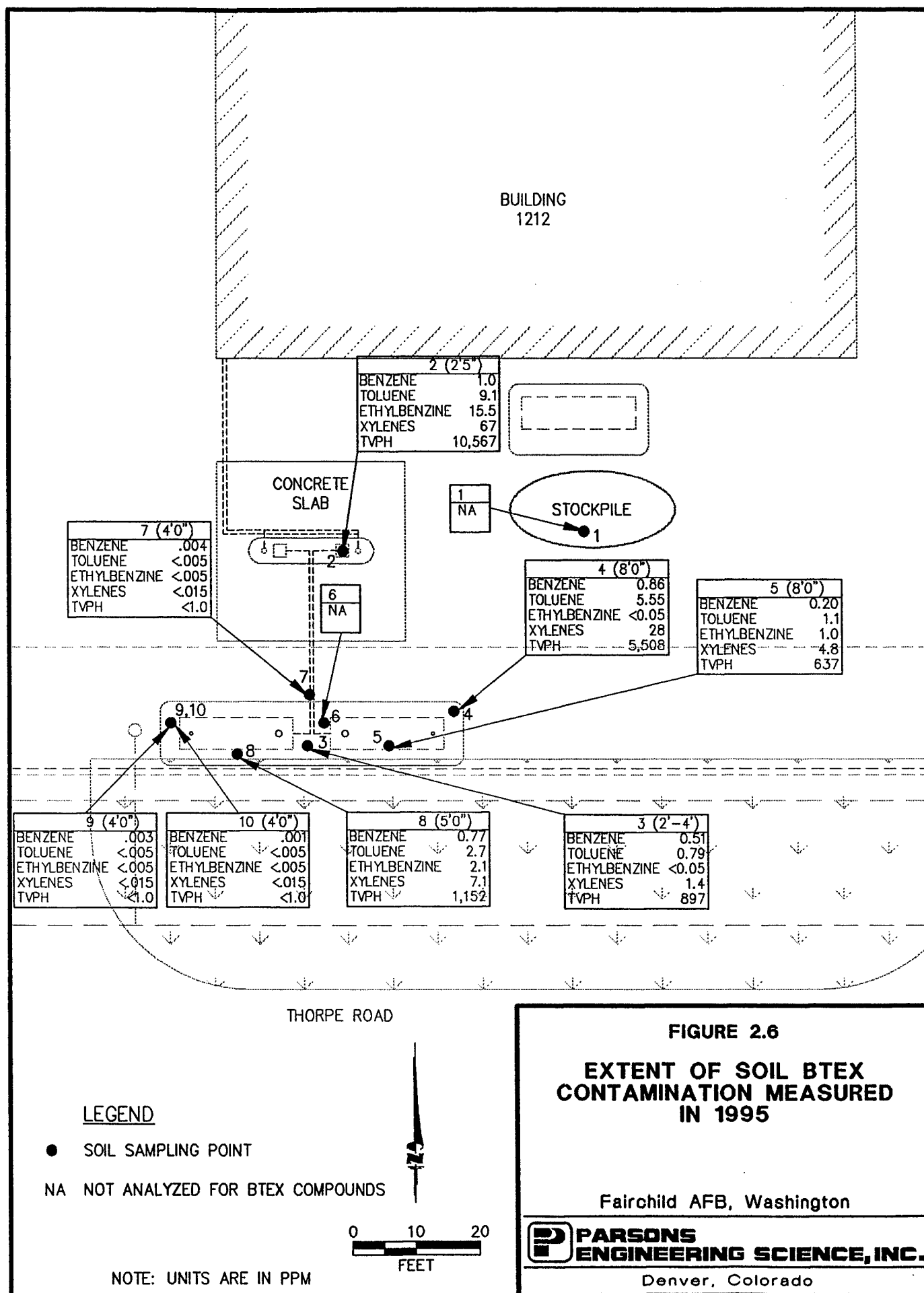


TABLE 2.1
SUMMARY OF 1995 SOIL ANALYTICAL DATA
BUILDING 1212 TS
REMEDIATION BY NATURAL ATTENUATION
FAIRCHILD AFB, WASHINGTON

Soil Sample Identification	Sampling Date	Sample Depth (feet bgs) ^{b/}	Sample					Total		TPH ^{a/} (ppm)	Lead (ppm)	Gasoline (ppm)	Diesel (ppm)	Heavy Petroleum Oils (ppm)
			Benzene (ppm) ^{c/}	Toluene (ppm)	Ethylbenzene (ppm)	Xylenes (ppm)	BTEX (ppm)							
1	10/4/95	NA ^{d/}	NA	NA	NA	NA	NA	NA	NA	NA	NA	>20	<50	<100
2	10/4/95	2.5'	1	9.1	15.5	67	92.6	92.6	10567	57	NA	NA	NA	NA
3	10/4/95	2'-4'	0.51	0.79	<0.05	1.4	2.7	2.7	897	NA	NA	NA	NA	NA
4	10/5/95	8'	0.86	5.55	<0.05	28	34.41	34.41	5508	NA	NA	NA	NA	NA
5	10/5/95	8'	0.2	1.1	1	4.8	7.1	7.1	637	NA	NA	NA	NA	NA
6	10/5/95	9'	NA	NA	NA	NA	NA	NA	NA	14	<20	<20	<50	<100
7	10/5/95	4'	0.004	<0.005	<0.005	<0.015	0.004	0.004	<1.0	NA	NA	NA	NA	NA
8	10/5/95	5'	0.77	2.7	2.1	7.1	12.67	12.67	1152	NA	NA	NA	NA	NA
9	10/5/95	4'	0.003	<0.005	<0.005	<0.015	0.003	0.003	<1.0	NA	NA	NA	NA	NA
10	10/5/95	4'	0.001	<0.005	<0.005	<0.015	0.001	0.001	<1.0	NA	NA	NA	NA	NA

Source: Budinger & Associates, 1995.

^{a/} TPH = total petroleum hydrocarbons.

^{b/} feet bgs = feet below ground surface.

^{c/} ppm = parts per million.

^{d/} NA = data not available.

Analytical data show that the presence of BTEX is minimal, compared to the total petroleum hydrocarbon (TPH) content of the soils, suggesting that gasoline released from the USTs and associated piping has weathered to a significant.

2.2 DEVELOPMENT OF CONCEPTUAL SITE MODEL

A CSM is a three-dimensional representation of a site's hydrogeologic system based on available geological, hydrological, climatological, and geochemical data. A CSM is developed to provide an understanding of the mechanisms controlling contaminant fate and transport and to identify additional data requirements. The model describes known and suspected sources of contamination, types of contamination, affected media, and contaminant migration pathways. The model also provides a foundation for formulating decisions regarding additional data collection activities and potential remedial actions. The CSM for Building 1212 will be used to aid in selecting additional data collection points and to identify appropriate data needs for modeling and hydrocarbon degradation using groundwater flow and solute transport models.

Successful conceptual model development involves:

- Defining the problem to be solved;
- Integrating available data, including
 - Local geologic and topographic data,
 - Hydraulic data,
 - Site stratigraphic data,
 - Contaminant concentration and distribution data;
- Evaluating contaminant fate and transport characteristics;
- Identifying contaminant migration pathways;
- Identifying potential receptors and receptor exposure points; and
- Determining additional data requirements.

2.2.1 RNA and Groundwater Flow and Solute Transport Models

After a site has been adequately characterized, fate and transport analyses can be performed to determine the potential for contaminant migration and whether any pathway for exposure of human or nonhuman (i.e., ecological) receptors to site contaminants may be complete. Groundwater flow and solute transport models have proven useful for predicting BTEX plume migration and contaminant attenuation by natural biodegradation. Analytical solute transport models and the Bioplume II

numerical model (Rifai *et al.*, 1988) can be used to evaluate critical groundwater fate and transport processes that may be involved in some of the migration pathways to human and ecological receptors. Quantitative fate and transport analyses can be used to determine what level and extent of remediation is required.

An accurate estimate of the potential for natural biodegradation of BTEX compounds in groundwater is important to consider when determining whether fuel hydrocarbon contamination presents a substantial threat to human health and the environment, and when deciding what type of remedial alternative will be most cost effective in eliminating or abating these threats. Over the past two decades, numerous laboratory and field studies have demonstrated that subsurface microorganisms can degrade a variety of hydrocarbons (Lee, 1988). This process occurs naturally when sufficient oxygen (or other electron acceptors) and nutrients are available in the groundwater. The rate of natural biodegradation is generally limited by the lack of oxygen (or other electron acceptors) rather than by the lack of nutrients such as nitrogen or phosphorus. The supply of oxygen to unsaturated soil is constantly renewed by vertical diffusion from the atmosphere. The supply of oxygen to a shallow, fuel-contaminated aquifer is constantly renewed by the influx of oxygenated, upgradient flow and recharge from precipitation and by the vertical diffusion of oxygen from the unsaturated soil zone into the groundwater (Borden and Bedient, 1986). The rate of natural biodegradation in unsaturated soil and shallow aquifers is largely dependent upon the types of and degree of weathering of contaminants present, and the rates at which oxygen and other electron acceptors enter the contaminated media.

2.2.2 Biodegradation of Dissolved BTEX Contamination

The positive effect of natural attenuation processes (e.g., advection, dispersion, sorption, and biodegradation) on reducing the actual mass of fuel-related contamination dissolved in groundwater has been termed RNA. To estimate the impact of natural attenuation on the fate and transport of BTEX compounds dissolved in groundwater at a site, two important lines of evidence must be demonstrated (Wiedemeier *et al.*, 1995). The first is a documented loss of contaminants at the field scale. Dissolved concentrations of biologically recalcitrant tracers found in most fuel contamination are used in conjunction with aquifer hydrogeologic parameters, such as groundwater seepage velocity and dilution, to demonstrate that a reduction in contaminant mass is occurring at the site. The second line of evidence involves the use of chemical analytical data in mass-balance calculations to show that areas with BTEX contamination can be correlated to areas with depleted electron acceptor (e.g., oxygen, nitrate, and sulfate) concentrations and increases in metabolic fuel degradation byproduct concentrations (e.g., methane and ferrous iron). With this site-specific information, groundwater flow and solute transport models can be used to simulate the fate and transport of dissolved BTEX compounds under the influence of natural attenuation.

Analytical and numerical models are available for modeling the fate and transport of fuel hydrocarbons under the influence of advection, dispersion, sorption, and natural aerobic and anaerobic biodegradation. Analytical models may be used in conjunction with the Bioplume II numerical model, as appropriate. The Bioplume II numerical model is based upon the USGS two-dimensional (2-D) solute transport model, which has been modified to include a biodegradation component that is activated by a superimposed plume of dissolved oxygen. Bioplume II solves the USGS 2-D solute equation twice, once for hydrocarbon concentrations in the groundwater and once for a dissolved oxygen plume. The two plumes are then combined using superimposition at every particle move to simulate biological reactions between fuel products and oxygen. As appropriate, biodegradation of contaminants by anaerobic processes is simulated using a first-order anaerobic decay rate.

The analytical solute transport models are derived from advection-dispersion equations given by Wexler (1992) and van Genuchten and Alves (1982). These models provide exact, closed-form solutions and are appropriately used for relatively simple hydrogeologic systems that are homogeneous and isotropic. Each model is capable of simulating advection, dispersion, sorption, and biodegradation (or any first-order decay process). These models can simulate continuous or decaying sources. A continuous source model is useful for determination of the worst-case distribution of the dissolved contaminant plume. A decaying source model is useful for simulating source removal scenarios, including natural weathering processes and engineered solutions.

2.2.3 Initial Conceptual Site Model

The surface of the groundwater table at Building 1212 at Fairchild AFB is present at approximately 6 to 9 feet bgs in a sandy silt, with traces of clay. Groundwater also occurs in shallow bedrock at a depth which is currently unknown. Local groundwater flow in the overburden is to the east, with an approximate gradient of 0.005 ft/ft. There are no known significant hydrogeologic or anthropogenic features in the area of Building 1212 that would likely interrupt the prevailing groundwater flow direction. On the basis of the available data, Parsons ES will model the site as an unconfined sandy silt aquifer. This CSM will be modified as necessary as additional site hydrogeologic data become available.

If mobile LNAPL is present at Building 1212 it will be necessary to use the fuel/water partitioning models of Bruce *et al.* (1991) or Cline *et al.* (1991) to provide a conservative source term to model the partitioning of BTEX from the mobile LNAPL into the groundwater. In order to use one of these models, samples of free product will be collected, if mobile LNAPL exists at Building 1212, and analyzed for mass fraction of BTEX. If free product is identified, Parsons ES also would collect groundwater samples from immediately below the LNAPL layer. Information from historical soil contamination data for the site (Table 2.1) will be used to select the locations of new monitoring wells to fully define the extents of possible LNAPL and the potential dissolved BTEX plumes at Building 1212.

Because of its solubility and relative toxicity, benzene is the primary chemical of interest in groundwater at Building 1212. However, the synergistic effects of all of the BTEX compound on attenuation rates make site data for all of the BTEX compounds important. Therefore, the BTEX compounds will be the primary focus of this RNA TS. The Bioplume II model will be used to simulate the degradation of these chemicals at Building 1212 and to predict the concentrations and extent of the contaminant plume in the groundwater over time.

Dissolved BTEX ~~at the site are expected to~~ leach from contaminated soils containing fuel residuals or to dissolve from mobile LNAPL into the groundwater, and to migrate downgradient as a dissolved contaminant plume. In addition to the effects of mass transport mechanisms (volatilization, dispersion, diffusion, and adsorption), these dissolved contaminants will likely be removed from the groundwater system by destructive attenuation mechanisms, such as biodegradation. The effects of these fate and transport processes on the dissolved groundwater plume will be investigated using the quantitative groundwater analytical data and the solute transport models. Data collection and analysis requirements are discussed in Section 3 of this work plan.

2.2.4 Potential Pathways and Receptors

Potential preferential contaminant migration pathways such as groundwater discharge points and subsurface utility corridors (artificial conduits) will be identified during the field work phase of this project. The primary potential migration paths for contaminants at Building 1212 are from residual LNAPL in contaminated soils and possible mobile LNAPL at the site into the groundwater, and from the groundwater to potential receptors via ingestion or incidental contact.

Shallow groundwater beneath Building 1212 flows in an easterly direction. There are no known operating potable or nonpotable water wells (other than monitoring wells) located within 1 mile downgradient or crossgradient from the site. Surface drainage by overland flow from the site is guided by positive-sloped asphalt/pavement to the west, north, and east. Stormwater is directed to lawn areas from streets and lots. Surface soil contamination at the site is limited, and is not expected to impact surface runoff water quality.

The potential for exposure to contaminated water originating from the site through ingestion is low because Base access is restricted and Base drinking water does not come from wells located downgradient from Building 1212. There are residential areas that rely on domestic wells for drinking water near the eastern boundary of the Base. The closest known residential housing downgradient from the site is across Rambo Road adjacent to the eastern Base boundary, approximately 6,000 feet from the site. Site contaminants are not expected to migrate to these drinking water wells at concentrations exceeding regulatory levels intended to be protective of human health and the environment. However, the potential impacts on these wells will be of primary importance for assessing the feasibility of RNA at Building 1212 and will be considered

in greater detail once additional site data essential for the evaluation of RNA have been collected.

SECTION 3

COLLECTION OF ADDITIONAL DATA

To complete the TS and to demonstrate that RNA of fuel-related contaminants is occurring, additional site-specific hydrogeologic data will be collected at Building 1212. The physical and chemical hydrogeologic parameters listed below will be determined during the field work phase of the TS.

Physical hydrogeologic characteristics to be determined include:

- Depth from measurement datum to the groundwater surface in site monitoring wells;
- Locations of potential groundwater preferential flow pathways and recharge and discharge areas;
- Locations of downgradient wells and their uses;
- Hydraulic conductivity through slug tests, as required;
- Estimate of dispersivity, where possible;
- Stratigraphic analysis of subsurface media;
- Groundwater temperature; and
- Determination of extent and thickness of mobile and residual LNAPL.

Chemical hydrogeologic characteristics to be determined include:

- Dissolved oxygen concentration;
- Specific conductance;
- Reduction/Oxidation (redox) potential;
- pH;
- Chemical analysis of mobile LNAPL (if present) to determine mass fraction of BTEX; and
- Additional chemical analysis of groundwater and soil for the parameters listed in Table 3.1.

TABLE 3.1
ANALYTICAL PROTOCOL
GROUNDWATER AND SOIL SAMPLES
BUILDING 1212 TS
REMEDIATION BY NATURAL ATTENUATION
FAIRCHILD AFB, WASHINGTON

MATRIX Analyte	METHOD	FIELD (F) OR FIXED-BASE LABORATORY (L)
WATER		
Total Iron	Colorimetric, HACH® Method 8008	F
Ferrous Iron (Fe ²⁺)	Colorimetric, HACH® Method 8146	F
Ferric Iron (Fe ³⁺)	Difference between total and ferrous iron	F
Manganese	Colorimetric, HACH® Method 8034	F
Sulfate	Colorimetric, HACH® Method 8051	F
Nitrate	Titrimetric, HACH® Method 8039	F
Nitrite	Titrimetric, HACH® Method 8507	F
Redox Potential	A2580B, direct-reading meter	F
Oxygen	Direct-reading meter	F
pH	E150.1/SW9040, direct-reading meter	F
Conductivity	E120.1/SW9050, direct-reading meter	F
Temperature	E170.1, direct-reading meter	F
Carbon Dioxide	Titrimetric, HACH® Method 1436-01	F
Alkalinity (Carbonate [CO ₃ ²⁻] and Bicarbonate [HCO ₃ ⁻])	F = Titrimetric, HACH® Method 8221 L = USEPA Method 310.1	F L
Nitrate + Nitrite	USEPA Method 353.1	L
Chloride	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane	RSKSOP-147	L
Dissolved Organic Carbon	RSKSOP-102	L
Aromatic Hydrocarbons	RSKSOP-148	L
Fuel Carbon	RSKSOP-148	L
SOIL		
Total Organic Carbon	RSKSOP-102 & RSKSOP-120	L
Moisture	ASTM D-2216	L
Aromatic Hydrocarbons	RSKSOP-124, modified	L
Total Hydrocarbons	RSKSOP-174	L
FREE PRODUCT		
BTEX Mass Fraction	RSKSOP-124, modified	L

In order to obtain these data, soil, groundwater, free product (if present) samples will be collected and analyzed. The following sections describe the procedures that will be followed when collecting additional site-specific data. Split-spoon sampling and monitoring well installation will be accomplished using a HSA drill rig, as described in Section 3.1. Groundwater sampling procedures for newly installed monitoring wells are described in Section 3.2. Sample handling procedures are discussed in Section 3.3. Measurement procedures for aquifer parameters (e.g., hydraulic conductivity) are described in Section 3.4.

3.1 DRILLING, SOIL SAMPLING, AND MONITORING WELL INSTALLATION

To further characterize the hydrogeologic conditions of the shallow subsurface for Bioplume II model development, up to 16 new groundwater monitoring wells will be installed at the Building 1212 site. The following sections describe the proposed well locations and completion intervals, equipment decontamination procedures, drilling and soil sampling, monitoring well installation, well development, and well location and datum surveying.

3.1.1 Well Locations and Completion Intervals

Up to 16 new wells will be installed to characterize the nature and extent of soil and groundwater contamination at the Building 1212 site. Eight of the new monitoring wells will be installed as nested pairs of wells at four locations to provide information on vertical flow gradients and vertical distribution of contaminants and other geochemical parameters. The proposed locations for the new monitoring wells were determined from a review of data gathered during previous site activities. Monitoring well locations were selected to provide hydrogeologic data necessary for successful implementation of the Bioplume II model and to monitor potential fuel hydrocarbon migration from the site. Monitoring well locations were selected to define four aspects of the site: 1) the presence of mobile LNAPL and dissolved BTEX concentrations within suspected source areas, 2) the vertical extent of potential dissolved contamination, 3) the horizontal distribution of potential dissolved BTEX, and 4) the hydrogeology and groundwater flow direction at the site. The proposed locations shown on Figure 3.1 may be modified in the field as a result of encountered field conditions and acquired field data. All nested wells will be installed with 5-foot screens, with the shallow well screened across the water table and the deep well screened approximately 10 to 15 feet below the bottom of the shallow well screen. Well completion depths are expected to range between approximately 10 and 30 feet bgs.

One background well will be placed approximately 30 feet upgradient from the concrete slab surrounding the fuel dispensers. Of the four nested pairs of deep and shallow wells, nested pairs are proposed for the two potential source areas judged to have the greatest potential for groundwater impact: the fuel dispensing island and the former location of the two gasoline USTs. Because drilling through the concrete slab surrounding the fuel dispensers may not be possible or permitted, an optional placement for this cluster is shown on Figure 3.1 immediately east of the pump island. The remaining two clusters are proposed for locations approximately 80 feet and 180

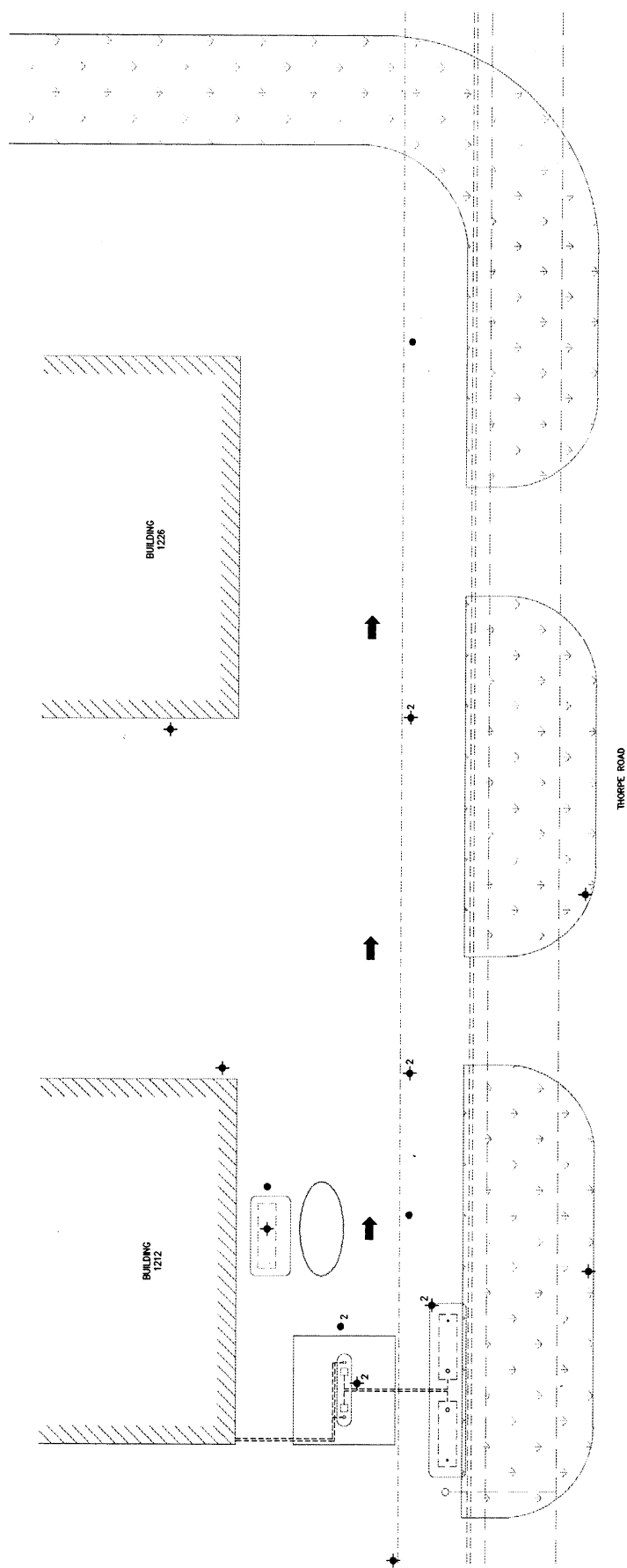
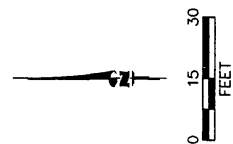


FIGURE 3.1
PROPOSED
MONITORING WELL
LOCATIONS



- LEGEND**
- ★ PROPOSED WELL LOCATION
 - PROPOSED OPTIONAL WELL LOCATION
 - ➡ APPROXIMATE DIRECTION OF GROUNDWATER FLOW

Fairchild AFB, Washington



Denver, Colorado

feet directly downgradient from the source area. Both of these proposed locations lie in paved lots along an east/west underground utility corridor. It is possible that backfill used along this utility corridor is more permeable than the surrounding native soils and could serve as a preferential flow pathway. If groundwater screening at the proposed location 80 feet from the former USTs does not indicate the presence of groundwater contamination, only a single well would be installed 180 feet downgradient from the UST site, and an additional well would be placed between the former gasoline UST excavation and the 80 feet downgradient. This optional well placement would help better define the extent of groundwater contamination in the event that the contaminated area is limited to no more than 80 feet east of the USTs.

In addition to the source-defining and background wells, several crossgradient and downgradient wells will be installed at the Building 1212 site. Figure 3.1 shows the approximate location of these additional wells. To the north of the proposed nested pairs, one well will be placed directly in or just downgradient from the excavation of the heating oil tank. Two others will be installed in the general vicinity of the southeast corner of Building 1212 and the southwest. To help define plume extents three more wells will be placed south of the site. One well will be approximately 40 feet south of the two gasoline USTs, in the lawn area, the second will be placed approximately 100 feet southeast of the source area in another lawn area, and the third well will be placed across Thorpe Road about even with the southeastern corner of Building 1216. One additional downgradient well location have been identified as an optional location (approximately 280 feet downgradient along the underground utility corridor) that would be installed if groundwater screening at the 180-foot nested pair indicates the presence of dissolved contamination. Final placement of all deep and shallow wells will be at the discretion of the site hydrogeologist.

3.1.2 Well Drilling and Installation Procedures

This subsection addresses the procedures for drilling and installing new monitoring wells. All new monitoring wells will be installed in accordance with general procedures outlined in Section 8.5 of *A Compendium of Superfund Field Methods* (USEPA, 1987).

3.1.2.1 Pre-Drilling Activities

All necessary digging, drilling, and groundwater monitoring well installation permits will be obtained prior to mobilizing to the field. In addition, all utility lines will be located, and proposed drilling locations will be cleared prior to any drilling activities. Personnel from Fairchild AFB will be responsible for these actions with the exception of obtaining state monitoring well permits, which will be accomplished by Parsons ES..

Water to be used in drilling, equipment cleaning, or grouting will be obtained from one of the Base's onsite water supplies. Water use approval will be verified by contacting the appropriate facility personnel. Only potable water will be used for the activities listed above. The field hydrogeologist will make the final determination as to the suitability of site water for these activities.

3.1.2.2 Equipment Decontamination Procedures

Prior to arriving at the site, and between each drilling site, the drill rig, augers, drilling rods, bits, casing, samplers, tools and other downhole equipment will be decontaminated using a high-pressure, steam/hot water wash. Only potable water will be used for decontamination.

During drilling operations, the drill rig, augers, and any downhole drilling and/or sampling equipment will be decontaminated at the onsite decontamination pad or another location specified by base personnel. Water from the decontamination operations will be collected in 55-gallon drums. Precautions will be taken to minimize any impact to the area surrounding the decontamination pad that might result from the decontamination operations.

All soil sampling tools will be cleaned onsite, prior to use and between each sampling event with a water/phosphate-free detergent solution and a water rinse. All well completion materials that are not factory sealed will be cleaned onsite prior to use with a high-pressure, steam/hot water wash using approved water. Materials that cannot be cleaned to the satisfaction of the field hydrogeologist will not be used. All decontamination activities must be conducted in a manner so that the excess water will be controlled and not allowed to flow into any open borehole.

If contaminated soils are encountered during drilling [based on visual, olfactory, or photoionization (PID) indications], and the potential for cross-contamination is anticipated, drilling will be stopped, and modified drilling procedures will be implemented to prevent the transfer of contaminants to deeper water-bearing strata. Fuel, lubricants, and other similar substances will be handled in a manner consistent with accepted safety procedures and standard operating practices. Well completion materials will not be stored near or in areas which could be affected by these substances.

Surface runoff such as miscellaneous spills and leaks, precipitation, and spilled drilling fluid will not be allowed to enter any boring or well either during or after drilling/well construction. Berms around the borehole or surficial bentonite packs, as appropriate, will be used to prevent this from happening.

3.1.2.3 Drilling and Soil Sampling

Drilling in unconsolidated soils will be accomplished using the HSA method. Boreholes will be drilled and continuously sampled to the proposed total depth of the monitoring well. In the case of nested well pairs, only the borehole of the deep well will be sampled and logged. A final borehole diameter of at least 6 inches will be required for the installation of wells with a 2-inch inside-diameter (ID) casing.

If subsurface conditions are such that the planned drilling technique does not produce acceptable results (e.g., unstable borehole walls or poor soil sample recovery), another technique deemed more appropriate to the type of soils present will be used. Any alternate soil sampling procedure used must be approved by the Parsons ES field hydrogeologist and will be appropriate for the subsurface lithologies present at the site.

Continuous soil samples will be obtained using a split-spoon (California type) sampling device or another similar method judged acceptable by the Parsons ES field hydrogeologist. Samples will be collected in each of the boreholes at approximately 2.5-foot intervals from 2.5 feet bgs to total depth unless an alternative sampling frequency is requested by the Parsons ES field hydrogeologist. Procedures will be modified, if necessary, to ensure good sample recovery. The soil samples collected will be removed from the continuous sampler and placed on clean aluminum foil for logging.

Representative portions of the soil samples will be collected for the headspace procedure and quickly transferred to clean containers, which will be sealed and held for 15 minutes at an ambient temperature of 65 degrees Fahrenheit (°F) or greater. Semiquantitative measurements will be made by puncturing the container seal with the PID probe and reading the concentration of the headspace gases. The PID relates the concentration of total volatile organic compounds (VOCs) in the sample to an isobutylene calibration standard. It is anticipated that headspace measurements will be performed on all samples collected during the drilling operations. The PID also will be used to monitor the worker breathing zone.

The Parsons ES field hydrogeologist will be responsible for observing all drilling and well installation activities, maintaining a detailed descriptive log of subsurface materials recovered, photographing representative samples, and properly labeling and storing samples. An example of the proposed geologic boring log form is presented in Figure 3.2. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination;
- Lithologic description, including relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- Depth of lithologic contacts and/or significant textural changes measured and recorded to the nearest 0.1 foot.

Soils generated during drilling operations will be stored onsite in a 10-cubic-yard covered roll-off container. Upon completion of the drilling activities, the roll-off container will be removed from the site, and soils will be transported to a disposal facility by Roartech of Spokane, Washington.

3.1.2.4 Borehole Abandonment

Any borehole not be completed as a monitoring well will be abandoned by backfilling with bentonite chips or a Portland[®] cement/sodium bentonite grout mixture to within approximately 3 feet of ground surface. If cement/sodium bentonite grout is used, the bentonite content of the grout will not exceed 8 percent by dry weight. If

GEOLOGIC BORING LOG

BORING NO.: _____ CONTRACTOR: _____ DATE SPUD: _____
 CLIENT: _____ RIG TYPE: _____ DATE CMPL.: _____
 JOB NO.: _____ DRLG METHOD: _____ ELEVATION: _____
 LOCATION: _____ BORING DIA.: _____ TEMP: _____
 GEOLOGIST: _____ DRLG FLUID: _____ WEATHER: _____
 COMMENTS: _____

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	1										
	5										
	10										
	15										
	20										
	25										
	30										
	35										

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB


 Water level drilled

FIGURE 3.2

GEOLOGIC BORING LOG

Fairchild AFB, Washington



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standing water is present in the borehole, the grout mixture will be placed using a tremie pipe placed below the static water level near the bottom of the borehole. The grout mixture will be pumped through the tremie pipe until undiluted grout is present in the borehole near ground surface.

Twenty-four hours after abandonment, the field hydrogeologist, or his designate, will check the abandoned site for grout settlement and specify additional grout, or backfill the hole to ground surface with clean native soil or concrete, as necessary.

3.1.2.5 Monitoring Well Installation

Groundwater monitoring wells are planned for installation in all boreholes. Wells in the Building 1212 area will be completed with flush-mount (at-grade) protective covers because of the site's current use as a filling station. Detailed well installation procedures are described in the following paragraphs.

3.1.2.5.1 Well Materials Decontamination

Well completion materials will be inspected by the field hydrogeologist and determined to be clean and acceptable for use. If not factory sealed, casing, screen, and casing plugs and caps will be cleaned before use with a high-pressure, steam/hot water cleaner using approved water. Prepackaged sand, bentonite, and Portland[®] cement will be used in well construction, and the bags will be inspected for possible external contamination before use. Materials that cannot be cleaned to the satisfaction of the field hydrogeologist will not be used.

3.1.2.5.2 Well Casing and Screen

Upon completion of drilling to the proper termination depth, monitoring well casing and screen will be installed. Well construction details will be noted on a Monitoring Well Installation Record form (Figure 3.3). This information will become part of the permanent field record for the site.

Well screens will be constructed of flush-threaded, Schedule 40 polyvinyl chloride (PVC) with an ID of 2 inches. Screens will be factory slotted with 0.010-inch openings. The position of the screen will be selected by the field hydrogeologist after consideration is given to the geometry and hydraulic characteristics of the stratum in which the well will be screened.

Blank well casing will be constructed of Schedule 40 PVC with an ID of 2 inches. All well casing sections will be flush-threaded; glued joints will not be used. The casing at each well will be fitted with a threaded bottom plug and a top cap constructed of the same type of material as the well casing. The top cap will be vented to maintain ambient atmospheric pressure within the well casing.

The field hydrogeologist will verify and record the boring depth, the lengths of all casing sections, and the depth to the top of all well completion materials placed in the annulus between the casing and borehole wall. All lengths and depths will be measured to the nearest 0.1 foot.

MONITORING WELL INSTALLATION RECORD

JOB NAME FAIRCHILD AIR FORCE BASE WELL NUMBER _____

JOB NUMBER 722450.18 INSTALLATION DATE _____ LOCATION _____

DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____

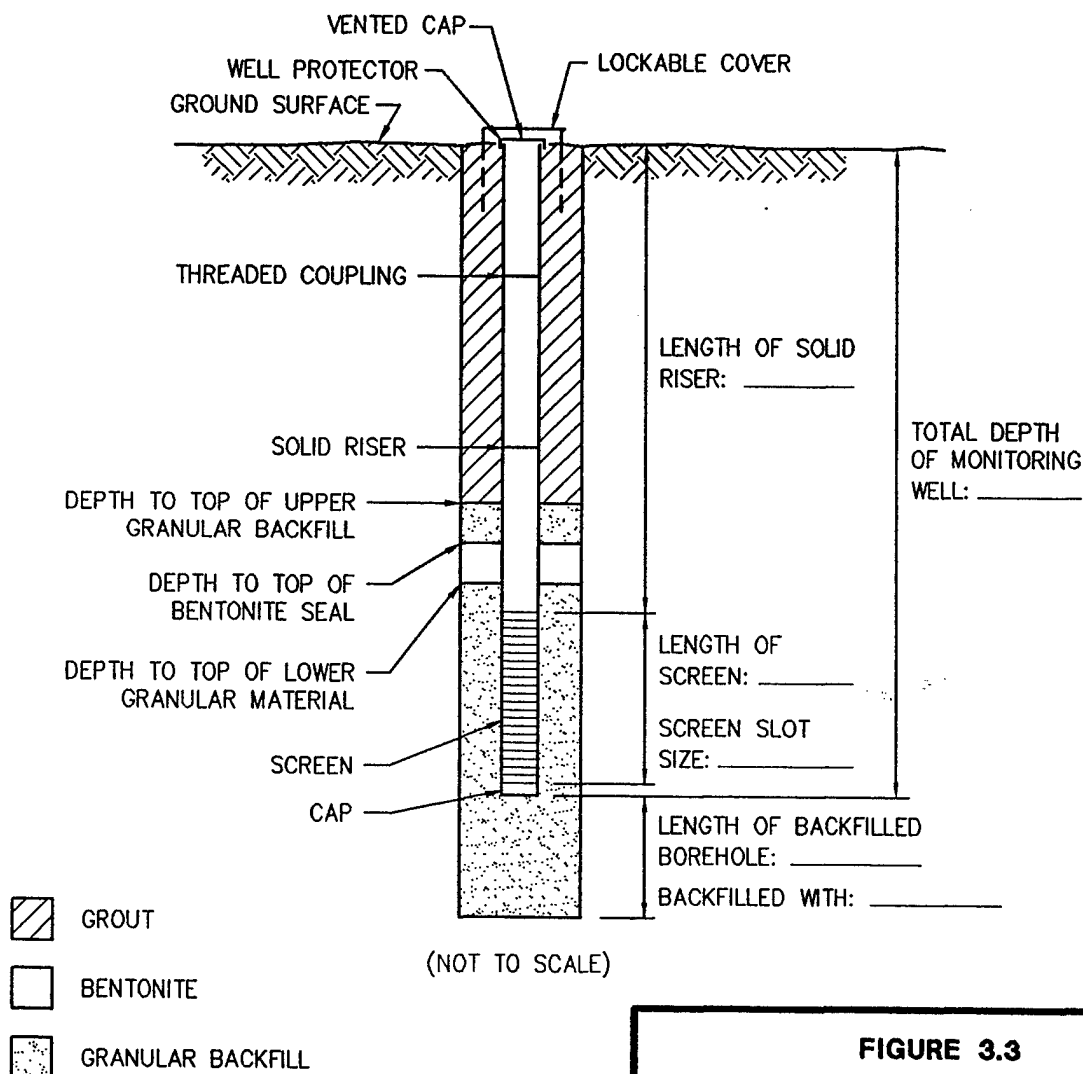
DATUM FOR WATER LEVEL MEASUREMENT _____

SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 8 INCHES

GRANULAR BACKFILL MATERIAL _____ ES REPRESENTATIVE _____

DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR _____



STABILIZED WATER LEVEL _____ FEET
BELOW DATUM.
MEASURED ON _____

FIGURE 3.3

MONITORING WELL INSTALLATION RECORD

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3.1.2.5.3 Filter Pack and Annular Seal

A graded sand filter will be placed around the screened interval and will extend at least 2 feet above the top of the screen. The sand filter will consist of 10-20 silica sand. For wells constructed in the Building 1212 area, a filter pack seal will be placed above the filter pack using sodium bentonite pellets. The pellet seal will be a minimum of 2 feet thick and will be hydrated in place with potable water. The pellet seal will be overlain by a Portland® cement/sodium bentonite grout that will extend from the top of the pellet seal to approximately 5 feet bgs. The cement/sodium bentonite grout will consist of one 94-pound sack of cement and about 5 pounds of bentonite for each 7 gallons of water used. The bentonite content of the cement/bentonite will not exceed 8 percent by dry weight. The grout will be overlain by concrete that will extend to the ground surface. To reduce heaving of the newly-installed monitoring well caused by freeze-thaw processes and to support the flush-mount protective cover, it is imperative that the uppermost concrete seal extend to at least 5 feet bgs. Construction details for well completion are presented schematically on Figure 3.4.

After the bentonite seal is emplaced, it will be allowed to settle for approximately 24 hours. Any settling will be topped off with bentonite pellets which will be hydrated with potable water. The bentonite will be topped off with sand to minimize dehydration of the bentonite, and a gravel mat will be placed over the sand to prevent damage to the surface of the seal.

3.1.2.5.4 Protective Covers

Each monitoring well in the Building 1212 area will be completed with an at-grade (flush-mount) protective cover (Figure 3.4). In areas where pavement is present, the at-grade cover will be cemented in place using concrete that will be blended to the existing pavement. In areas where pavement is not already present, a 6-inch-thick, 2-foot-diameter concrete pad will be constructed around the protective cover. In either case, the concrete immediately surrounding the well cover will be sloped gently away from the protective casing to facilitate runoff during precipitation events.

3.1.3 Well Development

Before any new well can be considered in proper condition for monitoring water levels or taking water samples, it must be developed. Development removes sediment from inside the well casing and flushes fines, cuttings, and drilling fluids from the sand pack and the portion of the formation adjacent to the well screen.

Well development will be accomplished using a peristaltic or 2-stage pump. The pump tubing will be regularly lowered to the bottom of the well so that fines that have accumulated in the bottom are agitated and removed from the well in the development water.

Development will be continued until a minimum of 10 casing volumes of water have been removed from the well and the water pH, temperature, and specific conductivity have stabilized. If the development water still is turbid after removal of 10 casing

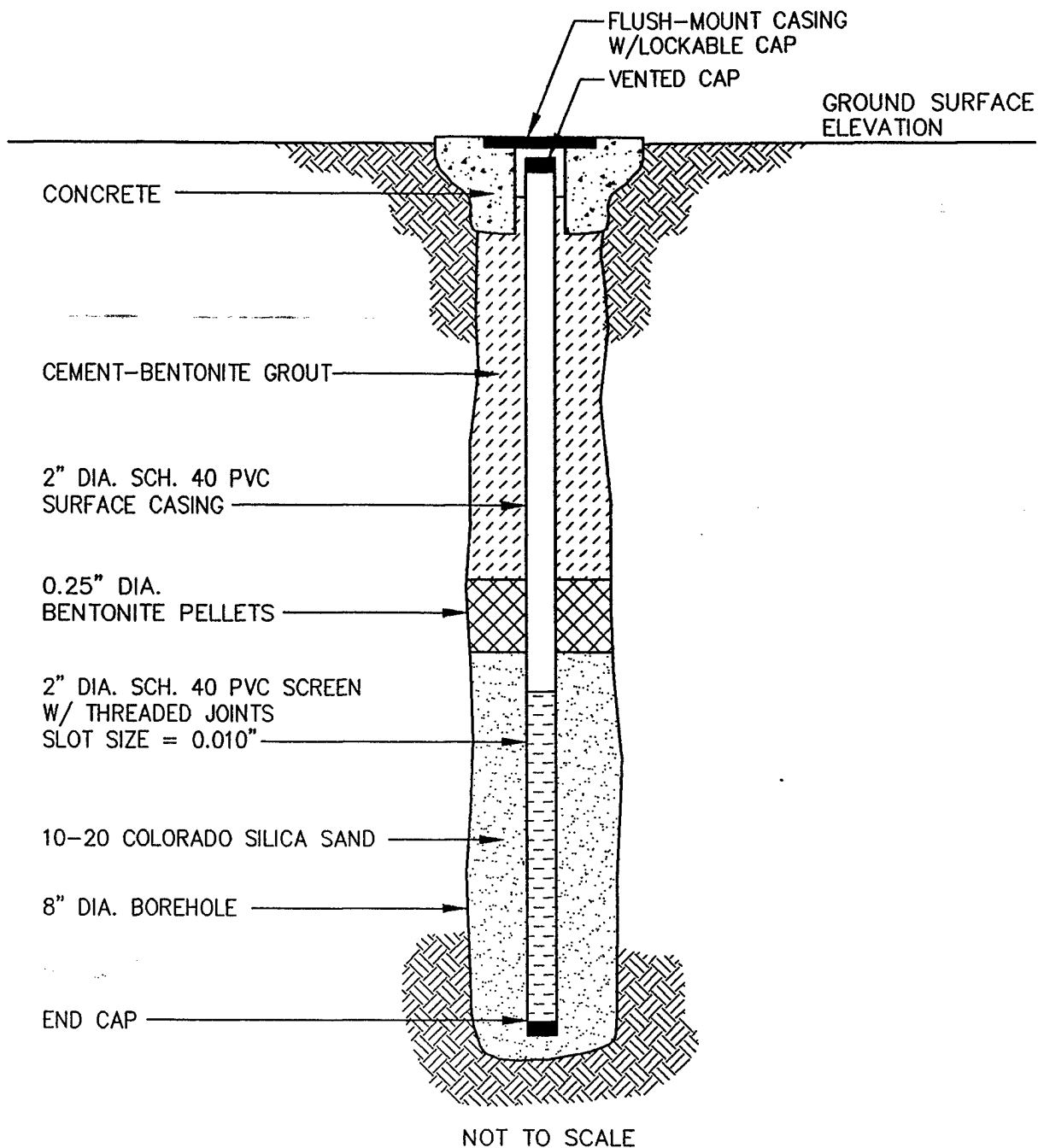


FIGURE 3.4

**TYPICAL MONITORING WELL
COMPLETION DIAGRAM**

Fairchild AFB, Washington



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volumes, development will be continued until the water becomes clear or the turbidity of the water produced has been stable after the removal of several additional casing volumes.

The development procedure specifies that 10 casing volumes of water be removed from the well. However, some wells completed in marginal aquifers will go dry during well development prior to the recovery of 10 casing volumes. In these low-productivity wells, development activity may have to be staged over a period of time to allow water to refill the well bore. In the event 10 casing volumes of water cannot be recovered, the water volume recovered and the deficiency will be noted in the development records.

Development waters not contaminated with mobile LNAPL will be collected in 55-gallon drums and transported daily to the Fairchild AFB carbon treatment plant for treatment and disposal. Development water contaminated with mobile LNAPL will be collected and stored in 55-gallon drums until the end of the sampling effort. The drums then will be turned over to the Base's waste oil contractor for proper disposal. The Base will be responsible for signing required shipping and disposal manifests.

A record of well development will be maintained for each well. The well development record will be maintained in a bound field notebook by the field hydrogeologist. Figure 3.5 is an example of the well development record. A summary well development record form will be prepared for each well and submitted with the TS report. Development records will include:

- Well number;
- Date and time of development;
- Development method;
- Pre-development water level and well depth;
- Volume of water produced;
- Description of water produced;
- Post-development water level and well depth; and
- Field analytical measurements, including pH and specific conductivity.

3.1.4 Water Level Measurements

Water levels at the monitoring wells will be measured within a short time interval so that the water-level data are comparable. Water levels in the wells will not be measured until they are developed and the water level has stabilized. The depth to water below the measurement datum will be made using an electronic water level probe to the nearest 1/8 inch (0.01 foot). In wells where mobile LNAPL may be encountered, an oil/water interface probe will be used to measure the depths to product and water.

MONITORING WELL DEVELOPMENT RECORD

Job Number: 722450.18

Job Name: Fairchild AFB, Washington

Location _____

by _____ Date: _____

Well Number _____ Measurement Datum _____

Pre-Development Information

Time (Start): _____

Water Level: _____

Total Depth of Well: _____

Water Characteristics

Color _____ Clear Cloudy

Odor: None Weak Moderate Strong

Any Films or Immiscible Material _____

pH _____ Temperature(°C) _____

Specific Conductance(μS/cm) _____

Interim Water Characteristics

Gallons Removed _____

pH _____

Temperature (°C) _____

Specific Conductance(μS/cm) _____

Post-Development Information

Time (Finish): _____

Water Level: _____

Total Depth of Well: _____

Approximate Volume Removed: _____

Water Characteristics

Color _____ Clear Cloudy

Odor: None Weak Moderate Strong

Any Films or Immiscible Material _____

pH _____ Temperature(°C) _____

Specific Conductance(μS/cm) _____

Comments:

FIGURE 3.5

MONITORING WELL DEVELOPMENT RECORD

Fairchild AFB, Washington



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3.1.5 Well Location and Datum Survey

The location and elevation of the new wells will be surveyed by a registered surveyor soon after well completion. Horizontal locations will be measured relative to established Fairchild AFB coordinates. Horizontal coordinates will be measured to the nearest 0.01 foot. Vertical location of the ground surface adjacent to the well casing, the measurement datum (top of the interior casing), and the top of the outer well casing will be measured relative to a US Geological Survey (USGS) msl datum. The ground surface elevation will be measured to the nearest 0.1 foot, and the measurement datum, outer casing, and surveyor's pin (if present) elevation will be measured to the nearest 0.01 foot.

3.1.6 Site Restoration

After well installation and sampling are complete, each well site will be restored as closely as possible to its original condition. Soils generated during drilling operations that were stored onsite in the 10-cubic-yard covered roll-off container will be removed from the site and transported to a disposal facility by Roartech. Water collected and stored in 55-gallon drums either will be taken to the Base's carbon treatment plant or will be removed by the Base waste oil contractor for proper disposal.

3.2 GROUNDWATER SAMPLING PROCEDURES

This section describes the scope of work required for collection of groundwater quality samples. Samples will be collected from all site monitoring wells. A peristaltic pump with dedicated high-density polyethylene (HDPE) tubing will be used to collect groundwater samples from the monitoring wells. In order to maintain a high degree of QC during this sampling event, the procedures described in the following sections will be followed.

Sampling will be conducted by qualified scientists and technicians from Parsons ES and the USEPA NRMRL who are trained in the conduct of groundwater sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan prior to sample acquisition and will have a copy of the work plan available onsite for reference. Groundwater sampling includes the following activities:

- Assembly and preparation of equipment and supplies;
- Inspection of the monitoring well integrity including:
 - Protective cover, cap, and lock,
 - External surface seal and pad,
 - Monitoring well stick-up, cap, and datum reference, and
 - Internal surface seal;
- Groundwater sampling, including:
 - Water level and product thickness measurements,

- Visual inspection of sample water,
- Monitoring well casing evacuation, and
- Sample collection;
- Sample preservation and shipment, including:
 - Sample preparation,
 - Onsite measurement of physical parameters, and
 - Sample labeling;
- Completion of sampling records; and
- Sample disposition.

Detailed groundwater sampling and sample handling procedures are presented in following sections.

3.2.1 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to leaving the office.

3.2.1.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before each use. This includes the split-spoon soil samplers, sampling pumps, water level probe and cable, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Given the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Wash with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);
- Rinse with potable water;
- Rinse with isopropyl alcohol;
- Rinse with distilled or deionized water; and
- Air dry.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the groundwater sampling record (Figure 3.6).

If precleaned disposable sampling equipment is used, the cleaning protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory. The type of container provided and the method of container decontamination will be documented in the USEPA mobile laboratory's permanent record of the sampling event.

GROUNDWATER SAMPLING RECORD

SAMPLING LOCATION _____

SAMPLING DATE(S) _____

MONITORING WELL _____

(number)

REASON FOR SAMPLING: ☐ Regular Sampling; ☐ Special Sampling;

DATE AND TIME OF SAMPLING: _____, 19____ a.m./p.m.

SAMPLE COLLECTED BY: _____ of _____

WEATHER: _____

DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____

MONITORING WELL CONDITION:

☐ LOCKED:

☐ UNLOCKED

WELL NUMBER (IS - IS NOT) APPARENT

STEEL CASING CONDITION IS: _____

INNER PVC CASING CONDITION IS: _____

WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe): _____

Check-off

1 ☐

EQUIPMENT CLEANED BEFORE USE WITH _____

Items Cleaned (List): _____

2 ☐

PRODUCT DEPTH _____ FT. BELOW DATUM

Measured with: _____

WATER DEPTH _____ FT. BELOW DATUM

Measured with: _____

3 ☐

WATER-CONDITION BEFORE WELL EVACUATION (Describe):

Appearance: _____

Odor: _____

Other Comments: _____

4 ☐

WELL EVACUATION:

Method: _____

Volume Removed: _____

Observations:

Water (slightly - very) cloudy

Water level (rose - fell - no change)

Water odors: _____

Other comments: _____

FIGURE 3.6

GROUNDWATER SAMPLING RECORD

Fairchild AFB, Washington



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MONITORING WELL

[] Bailer made of: _____
[] Pump, type: _____
[] Other, describe: _____

Temp: _____ ° _____	Measured with: _____
pH: _____	Measured with: _____
Conductivity: _____	Measured with: _____
Dissolved Oxygen: _____	Measured with: _____
Redox Potential: _____	Measured with: _____
Salinity: _____	Measured with: _____
Nitrate: _____	Measured with: _____
Sulfate: _____	Measured with: _____
Ferrous Iron: _____	Measured with: _____
Other: _____	

[] Filtration: Method _____ Containers: _____
Method _____ Containers: _____
Method _____ Containers: _____

[] Preservatives added:

Method _____	Containers: _____
Method _____	Containers: _____
Method _____	Containers: _____
Method _____	Containers: _____

- ☐ Container Sides Labeled
- ☐ Container Lids Taped
- ☐ Containers Placed in Ice Chest

10 [] OTHER COMMENTS: _____

Fairchild AFB, Washington



Denver, Colorado

3.2.1.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturers' specifications prior to field use. This applies to equipment used for onsite measurements of dissolved oxygen (DO), pH, electrical conductivity, temperature, redox potential, sulfate, nitrate, ferrous iron (Fe^{2+}), and other field parameters listed on Table 3.1.

3.2.2 Sampling Procedures

Special care will be taken to prevent contamination of the groundwater and extracted samples. The primary ways in which sample contamination can occur is through contact with improperly cleaned sampling equipment. To prevent such contamination, the water level probe and cable used to determine static water levels and total well depths will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.3.1.1. Dedicated tubing will be used at each well developed, purged, and/or sampled with the peristaltic pump. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile or latex gloves will be worn each time a different monitoring well is sampled. The following paragraphs present the procedures to be followed for groundwater sample collection from groundwater monitoring wells. These activities will be performed in the order presented below. Exceptions to this procedure will be noted in the field scientist's field notebook or on the groundwater sampling record.

3.2.2.1 Preparation of Location

Prior to starting the sampling procedure, the area around the monitoring wells will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring well.

3.2.2.2 Water Level and Total Depth Measurements

Prior to removing water from the monitoring well, the static water level will be measured. An electric water level probe or oil/water interface probe will be used to measure the depth to groundwater below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the monitoring well and the depth will be measured to the nearest 0.01 foot. If free-phase product (mobile LNAPL) is present, the total depth of the well from installation records will be used to avoid excessive contamination of the water level probe and cord. Based on these measurements, the volume of water to be purged from the monitoring well will be calculated. If mobile LNAPL is encountered, the thickness of the product will be measured with an oil/water interface probe.

3.2.2.3 Monitoring Well Purging

If well development occurred more than 24 hours before sampling is to begin, the monitoring well must be purged. The volume of water contained within the monitoring well casing at the time of sampling will be calculated, and at least three times the calculated volume will be removed from the well. A peristaltic pump will be used for

monitoring well purging. All purge waters will be collected in 55-gallon drums and managed in the manner described for development waters (see Section 3.1.3).

If a monitoring well is evacuated to a dry state during purging, the well will be allowed to recharge, and the sample will be collected as soon as sufficient water is present in the monitoring well to obtain the necessary sample quantity. Sample compositing or sampling over a lengthy period by accumulating small volumes of water at different times to obtain a sample of sufficient volume will not be allowed.

3.2.2.4 Sample Extraction

Dedicated HDPE tubing and a peristaltic pump will be used to extract groundwater samples from monitoring wells. The tubing will be lowered through the casing into the water gently to prevent splashing. The sample will be transferred directly into the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the USEPA mobile laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be disposed of in the same manner as purge water.

3.2.3 Onsite Groundwater Parameter Measurement

As indicated on Table 3.1, many of the groundwater chemical parameters will be measured onsite by USEPA staff. Some of the measurements will be made with direct-reading meters, while others will be made using a Hach® portable colorimeter in accordance with specific Hach® analytical procedures. These procedures are described in the following subsections.

All glassware or plasticware used in the analyses will have been cleaned prior to sample collection by thoroughly washing with a solution of laboratory-grade, phosphate-free detergent (e.g., Alconox®) and water, and rinsing with isopropyl alcohol and deionized water to prevent interference or cross-contamination between measurements. If concentrations of an analyte are above the range detectable by the titrimetric or colorimetric methods, the analysis will be repeated by diluting the groundwater sample with distilled water until the analyte concentration falls to a level within the range of the method. All rinseate and sample reagents accumulated during groundwater analysis will be collected in glass containers fitted with screw caps and properly disposed of

3.2.3.1 Dissolved Oxygen Measurements

DO measurements will be made using a meter with a downhole oxygen sensor or a sensor in a flow-through cell before groundwater sample acquisition.

3.2.3.2 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of a groundwater sample can change significantly within a short time following sample acquisition, these parameters

will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made in a flow-through cell or a clean glass container separate from those intended for laboratory analysis, and the measured values will be recorded in the groundwater sampling record (Figure 3.6).

3.2.3.3 Reduction/Oxidation Potential

The redox potential of groundwater is an indication of the relative tendency of a solution to accept or transfer electrons. Redox reactions in groundwater are usually biologically mediated; therefore, the redox potential of a groundwater system depends upon and influences rates of biodegradation. Redox potential can be used to provide real-time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. The redox potential of a groundwater sample taken inside the contaminant plume should be somewhat less than that taken in an upgradient location.

The redox potential of a groundwater sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. As a result, this parameter will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made as quickly as possible in a clean glass container separate from those intended for laboratory analysis, or in a flow-through cell.

3.2.3.4 Alkalinity Measurements

Alkalinity in groundwater helps buffer the groundwater system against acids generated through both aerobic and anaerobic biodegradation processes. Alkalinity of the groundwater sample will be measured in the field by experienced USEPA NRMRL scientists via titrimetric analysis using USEPA-approved Hach® Method 8221 (0 to 5,000 mg/L as calcium carbonate) or a similar method. Alkalinity of the groundwater sample also will be measured at the fixed-based laboratory using USEPA Method 310.1.

3.2.3.5 Nitrate- and Nitrite-Nitrogen Measurements

Nitrate-nitrogen concentrations are of interest because nitrate can act as an electron acceptor during hydrocarbon biodegradation under anaerobic soil or groundwater conditions. Nitrate-nitrogen also is a potential nitrogen source for biomass formation for hydrocarbon-degrading bacteria. Nitrite-nitrogen is an intermediate byproduct in both ammonia nitrification and in nitrate reduction in anaerobic environments.

Nitrate- and nitrite-nitrogen concentrations in groundwater will be measured in the field by experienced USEPA NRMRL scientists via colorimetric analysis using a Hach® DR/700 Portable Colorimeter. Nitrate concentrations in groundwater samples will be analyzed after preparation with Hach® Method 8039 (0 to 30.0 mg/L NO₃) or similar method. Nitrite concentrations in groundwater samples will be analyzed after preparation with USEPA-approved Hach® Method 8507 (0 to 0.35 mg/L NO₂) or a

similar method. Nitrate and nitrite also will be measured at the fixed-base laboratory using USEPA Method 353.1.

3.2.3.6 Sulfate Measurements

Sulfate in groundwater is a potential electron acceptor for fuel-hydrocarbon biodegradation in anaerobic environments. A USEPA NRMRL scientist will measure sulfate concentrations via colorimetric analysis with a Hach® DR/700 Portable Colorimeter. After appropriate sample preparation, USEPA-approved Hach® Method 8051 (0 to 70.0 mg/L SO_4) or similar methods will be used to prepare samples and analyze sulfate concentrations at the mobile laboratory.

3.2.3.7 Total Iron, Ferrous Iron, and Ferric Iron Measurements

Iron is an important trace nutrient for bacterial growth, and different states of iron can affect the redox potentials of the groundwater and act as an electron acceptor for biological metabolism under anaerobic conditions. Iron concentrations will be measured in the field via colorimetric analysis with a Hach® DR/700 Portable Colorimeter after appropriate sample preparation. Hach® Method 8008 (or similar) for total soluble iron (0 to 3.0 mg/L $\text{Fe}^{3+} + \text{Fe}^{2+}$) and Hach® Method 8146 (or similar) for ferrous iron (0 to 3.0 mg/L Fe^{2+}) will be used to prepare and quantitate the samples. Ferric iron will be quantitated by subtracting ferrous iron levels from total iron levels.

3.2.3.8 Manganese Measurements

Manganese is a potential electron acceptor under anaerobic environments. Manganese concentrations will be quantitated in the field using colorimetric analysis with a Hach® DR/700 Portable Colorimeter. USEPA-approved Hach® Method 8034 (0 to 20.0 mg/L) or similar will be used for quantitation of manganese concentrations.

3.2.3.9 Carbon Dioxide Measurements

Carbon dioxide concentrations of interest because carbon dioxide is a byproduct of all biodegradation reactions. Additionally, carbon dioxide in groundwater is a potential electron acceptor for methanogenic biodegradation under anaerobic conditions. Carbon dioxide concentrations in groundwater will be measured in the field by USEPA NRMRL scientists via titrimetric analysis using Hach® Method 1436-01 (0 to 250 mg/L as CO_2) or similar method. Sample preparation and disposal procedures are the same as outlined at the beginning of Section 3.3.3.

3.3 SAMPLE HANDLING FOR FIXED-BASE LABORATORY ANALYSIS

This section describes the handling of samples from the time of sampling until the samples are delivered to USEPA field laboratory.

3.3.1 Sample Preservation

The USEPA mobile laboratory support personnel will add any necessary chemical preservatives prior to filling the sample containers. Samples will be prepared for

transportation to the analytical laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of as close to 4 degrees centigrade (°C) as possible. Samples will be delivered promptly to USEPA field laboratory personnel, who will be responsible for shipment of appropriate samples to the NRMRL in Ada, Oklahoma for analysis.

3.3.2 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the USEPA field laboratory (see Appendix A). The sample containers will be filled as described in Section 3.2.2.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (e.g., groundwater, soil);
- Sampling date;
- Sampling time;
- Preservatives added;
- Sample collector's initials; and
- Requested analyses.

3.3.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the onsite USEPA field laboratory. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Cushion samples to avoid breakage; and
- Add ice to container to keep samples cool.

The packaged samples will be delivered by hand to the USEPA field laboratory. Delivery will occur as soon as possible after sample acquisition.

3.3.4 Chain-of-Custody Control

Chain-of-custody documentation for the shipment of samples from the USEPA field laboratory to the NRMRL analytical laboratory in Ada, Oklahoma, will be the responsibility of the USEPA field personnel.

3.3.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
 - Sample appearance, and
 - Sample odor;
- Weather conditions;
- Water level prior to purging (groundwater samples only);
- Total monitoring well depth (groundwater samples only);
- Sample depth (soil samples only);
- Purge volume (groundwater samples only);
- Water level after purging (groundwater samples only);
- Monitoring well condition (groundwater samples only);
- Sampler's identification;
- Field measurements of pH, temperature, DO, and specific conductivity (groundwater samples only); and
- Any other relevant information.

Groundwater sampling information will be recorded on a groundwater sampling form. Figure 3.6 is an example of the groundwater sampling record. Soil sampling information will be recorded in the field log book and on the borehole log (Figure 3.2).

3.3.6 Laboratory Analyses

Laboratory analyses will be performed on all groundwater and soil samples, including the QA/QC samples described in Section 5. If mobile LNAPL is present, a sample of the product also will be analyzed. The analytical methods for this sampling event are listed in Table 3.1. Prior to sampling, USEPA NRMRL personnel will provide a sufficient number of analyte-appropriate sample containers for the samples to be collected for fixed-base analyses. All containers, preservatives, and shipping requirements will be consistent with USEPA protocol or those reported in Appendix A of this plan.

USEPA laboratory support personnel will specify the necessary QC samples and prepare appropriate QC sample bottles. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory. Containers, ice chests with adequate padding, and cooling media will be provided by USEPA NRMRL laboratory personnel. Sampling personnel will fill the sample containers and return the samples to the field laboratory.

3.4 AQUIFER TESTING

Slug tests will be conducted on selected monitoring wells to estimate the hydraulic conductivity of unconsolidated deposits at the site. This information is required to accurately estimate the velocity of groundwater and contaminants in the shallow saturated zone. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests can be used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 squared feet per day (ft^2/day). Slug testing can be performed using either a rising head or a falling head test; at the Building 1212 site, both methods will be used in sequence.

3.4.1 Definitions

- **Hydraulic Conductivity (K).** A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.
- **Transmissivity (T).** A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.
- **Slug Test.** Two types of testing are possible: rising head and falling head tests. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.
- **Rising Head Test.** A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing, or removing a submerged slug from the well.
- **Falling Head Test.** A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

3.4.2 Equipment

The following equipment will be used to conduct a slug test:

- Teflon[®], PVC, or metal slugs;
- Nylon or polypropylene rope;

- Electronic water level indicator;
- Pressure transducer/sensor;
- Field logbook/forms; and
- Automatic data recording instrument (such as the Hermit Environmental Data Logger[®], In-Situ, Inc. Model SE1000B, or equivalent).

3.4.3 General Test Methods

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Slug testing will proceed only after multiple water level measurements over time show that static water levels are in equilibrium. During the slug test, the water level change should be influenced only by the introduction (or removal) of the slug volume. Other factors, such as inadequate well development or extended pumping may lead to inaccurate results; slug tests will not be performed on wells containing mobile LNAPL. The field scientist will determine when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other downhole equipment will be decontaminated prior to and immediately after the performance of each slug test using the procedures described in Section 3.2.1.1.

3.4.4 Falling Head Test

The falling head test is the first step in the two-step slug testing procedure. The following steps describe procedures to be followed during performance of the falling head test.

1. Decontaminate all downhole equipment prior to initiating the test.
2. Open the well. Where wells are equipped with watertight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.
3. Prepare the aquifer slug test data form (Figure 3.7) with entries for:
 - Borehole/well number,
 - Project number,
 - Project name,
 - Aquifer testing team,
 - Climatic data,

AQUIFER SLUG TEST DATA SHEET

Location: _____	Client: AFCEE	Well No. _____
Job No.: 722450.18	Field Scientist _____	Date _____
Water Level _____	Total Well Depth _____	
Measuring Datum _____	Elevation of Datum _____	
Weather _____	Temp _____	
Comments _____		

[illegible]**FIGURE 3.7**

AQUIFER TEST DATA FORM

Fairchild AFB, Washington



**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

- Ground surface elevation,
 - Top of well casing elevation,
 - Identification of measuring equipment being used,
 - Page number,
 - Static water level, and
 - Date.
4. Measure the static water level in the well to the nearest 0.01 foot.
 5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.
 6. Lower the decontaminated slug into the well to just above the water level in the well.
 7. Turn on the data logger, and quickly lower the slug below the water table, being careful not to disturb the pressure transducer. Follow the owner's manual for proper operation of the data logger.
 8. Terminate data recording when the water level stabilizes in the well. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.5.5 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedure.

1. Measure the water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.
2. Initiate data recording and quickly withdraw the slug from the well. Follow the owner's manual for proper operation of the data logger.
3. Terminate data recording when the water level stabilizes in the well, and remove the pressure transducer from the well and decontaminate. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.5.6 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using AQT ESOLV™ (Geraghty and Miller, 1994) and the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined aquifer conditions.

SECTION 4

REMEDIAL OPTION EVALUATION AND TS REPORT

Upon completion of field work, the Bioplume II numerical groundwater model will be used to determine the fate and transport of BTEX dissolved in groundwater at Building 1212. On the basis of model predictions of contaminant concentrations and distribution over time and distance, and of potential receptors and exposure pathways, the potential for receptors to be exposed to BTEX concentrations above regulatory levels intended to be protective of human health and the environment will be assessed. If it is shown that RNA of BTEX compounds at the sites is sufficient to reduce concentrations to regulatory standards intended to be protective of human health and the environment before receptors are exposed to affected media, Parsons ES will recommend implementation of the RNA option. If RNA is chosen, Parsons ES will prepare a site-specific, long-term monitoring plan that will specify the locations of point-of-compliance monitoring wells and sampling frequencies.

If RNA is deemed inappropriate for use at Building 1212, institutional controls such as groundwater or land use restrictions will be evaluated to determine if they will be sufficient to prevent exposure of receptors to contaminant concentrations greater than standards intended to be protective of human health and the environment. If institutional controls are inappropriate, remedial options that could reduce risks to acceptable levels will be evaluated and the most appropriate remedial options will be recommended. Potential remedial options include, but are not limited to, bioslurping, groundwater pump-and-treat, enhanced biological treatment, bioventing, and air sparging. The reductions in dissolved BTEX concentrations that should result from remedial activities will be used to produce new input files for the groundwater models. The models will then be used to predict the BTEX source and plume (and risk) contaminant reductions that should result from remedial actions.

Upon completion of Bioplume II modeling and remedial option selection, a TS report detailing the results of the modeling and remedial option selection will be prepared. This report will follow the outline presented in Table 4.1 and will contain an introduction, site descriptions, identification of remediation objectives, description of remediation alternatives, an analysis of remediation alternatives, and the recommended remedial approach for each site. This report also will summarize the results of the site characterization activities described herein and provide a description of the models developed for the Building 1212 site.

TABLE 4.1
EXAMPLE TS REPORT OUTLINE
BUILDING 1212 TS
REMEDIATION BY NATURAL ATTENUATION
FAIRCHILD AFB, WASHINGTON

INTRODUCTION

Scope and Objectives
Site Background

SITE CHARACTERIZATION ACTIVITIES

Sampling and Aquifer Testing Procedures

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

Surface Features
Regional Geology and Hydrogeology
Site Geology and Hydrogeology
Climatological Characteristics

NATURE AND EXTENT OF CONTAMINATION

Source Characterization
Soil Chemistry
 Residual Contamination
 Total Organic Carbon
Groundwater Chemistry
 LNAPL Contamination
 Dissolved Contamination
 Groundwater Geochemistry
 Expressed Assimilative Capacity

GROUNDWATER MODEL

Model Description
Conceptual Model Design and Assumptions
Initial Model Setup
Model Calibration
Sensitivity Analysis
Model Results
Conclusions

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

Remedial Alternative Evaluation Criteria
 Long-Term Effectiveness
 Implementability (Technical, Administrative)
 Cost (Capital, Operating, Present Worth)
Factors Influencing Alternatives Development
 Program Objectives
 Contaminant Properties
 Site-Specific Conditions
Brief Description of Remedial Alternatives

TABLE 4.1
EXAMPLE TS REPORT OUTLINE
BUILDING 1212 TS
REMEDIATION BY NATURAL ATTENUATION
FAIRCHILD AFB, WASHINGTON

Intrinsic Remediation with Long-Term Monitoring
Other Alternatives
Evaluation of Alternatives
Recommended Remedial Approach

LONG-TERM MONITORING PLAN

Overview
Monitoring Networks
Groundwater Sampling

CONCLUSIONS AND RECOMMENDATIONS

APPENDICES: Supporting Data and Documentation
 Site-Specific Bioplume II Model Input and Results

SECTION 5

QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field replicates/duplicates and rinseate, field and trip blanks; decontamination of all equipment that contacts the sample medium before and after each use; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the USEPA mobile laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., groundwater), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and sample containers will be packaged in coolers with ice to maintain a temperature of as close to 4°C as possible.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 5.1.

QA/QC sampling will include collection and analysis of duplicate groundwater and replicate soil samples, rinseate blanks, field/trip blanks, and matrix spike samples. Refer to Appendix A for details on sample volume requirements. Internal laboratory QC analyses will involve the analysis of laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

Duplicate water and replicate soil samples will be collected at a frequency of 10 percent, or 1 for every 10 or fewer samples of similar matrix. Duplicate groundwater samples are collected by alternately filling sample and duplicate sample containers. Replicate soil samples are collected by capping adjacent brass sleeves from a split-spoon samples and submitting the two sleeves for the original and replicate analyses.

Rinseate samples will be collected at a frequency of 5 percent, or 1 for every 20 or fewer groundwater samples collected from groundwater monitoring wells. Because sampling equipment is designated for use during this sampling event, the rinseate sample will consist of a sample of distilled water poured into a new disposable bailer or run through a new set of pump tubing and subsequently transferred into a sample container provided by the laboratory. Rinseate samples will be analyzed for VOCs only.

TABLE 5.1
QA/QC SAMPLING PROGRAM
 BUILDING 1212 TS
 REMEDIATION BY NATURAL ATTENUATION
 FAIRCHILD AFB, WASHINGTON

QA/QC Sample Types	Frequency to be Collected and/or Analyzed	Analytical Methods
Duplicates/Replicates	2 Groundwater and 2 Soil Samples (10%)	VOCs, Total Fuel Carbon
Rinseate Blanks	1 Samples (5% of Groundwater Samples)	VOCs
Field Blanks	1 Samples (5% of Groundwater Samples)	VOCs
Trip Blanks	One per shipping cooler containing VOC samples	VOCs
Matrix Spike Samples	Once per sampling event per matrix	VOCs
Laboratory Control Sample	Once per method per matrix	Laboratory Control Charts (Method Specific)
Laboratory Method Blanks	Once per method per matrix	Laboratory Control Charts (Method Specific)

A field blank will be collected for every 20 or fewer groundwater samples to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for VOCs.

A trip blank will be analyzed to assess the effects of ambient conditions on sampling results during the transportation of samples. The trip blank will be prepared by the laboratory. One trip blank will be transported inside each shipping container that contains samples for VOC analysis. Trip blanks will be analyzed for VOCs.

Matrix spike and matrix spike duplicate samples will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs. LCSs and LMBs will be prepared internally by the laboratory and will be analyzed each day samples from the site are analyzed. Samples will be reanalyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by the laboratory and monitored for the analytical methods used.

- Geraghty & Miller, Inc., 1994, AQTESOLV[®] Aquifer Test Solver, Version 2.0
Millersville, Maryland October.
- Halliburton NUS (HNUS), 1993, *Installation Restoration Program (IRP) Remedial Investigation Report Priority One Operable Units: LF-01 (SW-1); SD-05 (IS-1); SS-18 (PS-2); SS-28 (PS-6); SS-27 (PS-8); WP-03 (WW-1); FT-04 (FT-1), Fairchild AFB, Washington.* February.
- ICF Technology, Inc. (ICF), 1995, *Long Term Monitoring Report for Priority 1 Sites SW-1 (LF-01), PS-2 (SS-18), and PS-8 (SS-26) at Fairchild AFB, Washington.* June.
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- Lee, M.D. 1988. Bioremediation of aquifers contaminated with organic compounds. *CRC Critical Reviews in Environmental Control*, v. 18. p. 29-89.
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- Science Applications International Corporation (SAIC), 1990, *Site Characterization Summary Priority One Sites.* December.
- US Environmental Protection Agency, 1987, A Compendium of Superfund Field Methods: EPA/540/P-87/001A. OSWER Directive 9355.0-14.
- US Geological Survey (USGS), 1973a, 7.5 Minute Quadrangle Map of the Four Lakes Quadrangle, Washington.
- USGS, 1973b, 7.5 Minute Quadrangle Map of the Medical Lake Quadrangle, Washington.
- USGS, 1986a, 7.5 Minute Quadrangle Map of the Airway Heights Quadrangle, Washington.
- USGS, 1986b, 7.5 Minute Quadrangle Map of the Deep Creek Quadrangle, Washington.
- van Genuchten, M. T., and Alves, W. J., 1982, *Analytical Solutions of the One-Dimensional Convective-Dispersive Solute Transport Equation:* US Department of Agriculture, Technical Bulletin Number 1661, 151p.
- Wexler, 1992, Analytical solutions for one-, two-, and three-dimensional solute transport in ground-water systems with uniform flow: *United States Geological Survey, Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3, Chapter B7, 190p.*

Wiedemeier, Todd H., Downey, Douglas C., Wilson, John T., Kampbell, Donald H., Miller, Ross N., and Hansen, Jerry E., 1995, *Draft Technical Protocol for Implementing the Intrinsic Remediation (Natural Attenuation) with Long-term Monitoring Option for Dissolved-phase Fuel Contamination in Ground Water*. Prepared by the Air Force Center for Environmental Excellence.

APPENDIX A

**CONTAINERS, PRESERVATIVES, PACKAGING, AND SHIPPING
REQUIREMENTS FOR ENVIRONMENTAL SAMPLES**

APPENDIX A

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Aromatic hydrocarbons (benzene, toluene, ethylbenzene, and xylene [BTEX]; trimethylbenzene isomers)	Purge and trap gas chromatography (GC) method SW8020	Handbook method modified for field extraction of soil using methanol	Data is used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal.	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data are used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal.	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	Procedure must be accurate over the range of 0.5–15 percent TOC	The rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the saturated zone soil.	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Moisture	ASTM D-2216	Handbook method	Data are used to correct soil sample analytical results for moisture content (e.g., report results on a dry weight basis)	Each soil sampling round	Use a portion of soil sample collected for another analysis	Fixed-base
Soil	Grain size distribution	ASTM D422	Procedure provides a distribution of grain size by sieving	Data are used to infer hydraulic conductivity of aquifer, and are used in calculating sorption of contaminants.	One time during life of project	Collect 250 g of soil in a glass or plastic container; preservation is unnecessary	Fixed-base

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Ferrous (Fe^{2+})	Colorimetric A3500-Fe D	Field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese.	Each sampling round	Collect 100 mL of water in a glass container; acidify with hydrochloric acid per method	Field
Water	Ferrous (Fe^{2+})	Colorimetric HACH Method # 8146	Alternate method; field only	Same as above.	Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Total Iron	Colorimetric HACH Method # 8008	Field only		Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Manganese	Colorimetric HACH Method # 8034	Field only		Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Chloride	Mercuric nitrate titration A4500- Cl^- C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system.	Each sampling round	Collect 250 mL of water in a glass container	Field
Water	Chloride	HACH Chloride test kit model 8-P	Silver nitrate titration	Same as above.	Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway.	Each sampling round	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen <i>in situ</i> .	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system.	Each sampling round	Collect 100–250 mL of water in a glass or plastic container	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Alkalinity	HACH Alkalinity test kit model AL AP MG-L	Phenolphthalein method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater.	Each sampling round	Collect 100mL of water in glass container	Field
Water	Alkalinity	A2320, titrimetric; E310.2, colorimetric	Handbook method	Same as above.	Each sampling round	Collect 250 mL of water in a glass or plastic container; analyze within 6 hours	Field
Water	Nitrate (NO_3^{-1})	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted.	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base
Water	Nitrate (NO_3^{-1})	HACH method # 8039 for high range method # 8192 for low range	Colorimetric	Same as above.	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Nitrite (NO)	HACH method #8040	Colorimetric	Substrate for microbial respiration if oxygen is depleted.	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Sulfate (SO_4^{-2})	IC method E300 or method SW9056	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for anaerobic microbial respiration.	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base
Water	Sulfate (SO_4^{-2})	HACH method # 8051	Colorimetric	Same as above.	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Dissolved sulfide (S ²⁻)	HACH method # 8131	Colorimetric	Product of sulfate-based anaerobic microbial respiration; analyze in conjunction with sulfate analysis.	Each sampling round	Collect 100 mL of water in a glass container; analyze immediately	Field
Water	Carbon dioxide	HACH test kit model CA-23 or CHEMetrics Method 4500	Titrimetric; alternate method	The presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate biodegradation of BTEX.	Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Methane	Kampbell <i>et al</i> , 1989 or SW3810 modified.	Method published and used by the U.S. Environmental Protection Agency (EPA) Nation Risk Management Research Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis).	Each sampling round	Collect water samples in 50 ml glass serum bottles with butyl gray/Teflon-lined caps; add H ₂ SO ₄ to pH 2; cool to 4°C	Fixed-base

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Aromatic hydrocarbons (BTEX, trimethylbenzene isomers)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for BTEX, which is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance; method can be extended to higher molecular weight alkyl benzenes; trimethylbenzenes are used to monitor plume dilution if degradation is primarily anaerobic.	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation; data also used to infer presence of an emulsion or surface layer of petroleum in water sample, as a result of sampling.	One time per year or as required by regulations	Volatile hydrocarbons—collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2 Extractable hydrocarbons—collect 1 L of water in a glass container; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Polycyclic aromatic hydrocarbons (PAHs) (optional)	GC/mass spectroscopy method SW8270; high-performance liquid chromatography method SW8310	Analysis needed only for several samples per site	PAHs are components of fuel and are typically analyzed for regulatory compliance; data on their concentrations are not used currently in the evaluation of natural attenuation.	At initial sampling and at site closure or as required by regulations	Collect 1 L of water in a glass container; cool to 4°C	Fixed-base

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Total fuel carbon (optional)	Purge and trap GC method SW8020 modified to measure all volatile aromatic hydrocarbons present in the sample	A substitute method for measuring total volatile hydrocarbons; reports amount of fuel as carbon present in the sample; method available from the U.S. EPA Robert S. Kerr Laboratory	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation.	At initial sampling and at site closure	Collect 40 mL of water in glass vials with Teflon-lined caps; add sulfuric acid to pH 2; cool to 4°C	Fixed-base
Water	Dissolved organic carbon (DOC) (optional)	A5310 C	An oxidation procedure whereby carbon dioxide formed from DOC is measured by an infrared spectrometer. The minimum detectable amount of DOC is 0.05 mg/L	An indirect index of microbial activity.	Each sampling round	Collect 100 mL of water in an amber glass container with Teflon-lined cap; preserve with sulfuric acid to pH less than 2; cool to 4°C	Fixed-base
Water	pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods	Aerobic and anaerobic processes are pH-sensitive.	Each sampling round	Collect 100-250 mL of water in a glass or plastic container; analyze immediately	Field
Water	Temperature	E170.1	Field only	Well development.	Each sampling round	N/A	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Each sampling round	Collect 100-250 mL of water in a glass container, filling container from bottom; analyze immediately	Field

NOTES:

1. "HACH" refers to the HACH Company catalog, 1990.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, U.S. Environmental Protection Agency, March 1979.
4. "Protocols" refers to the AFCEE *Environmental Chemistry Function Installation Restoration Program Analytical Protocols*, 11 June 1992.
5. "Handbook" refers to the AFCEE *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*, September 1993.
6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. Environmental Protection Agency, 3rd edition, 1986.

7. "ASTM" refers to the *American Society for Testing and Materials*, current edition.
8. "RSKSOP" refers to Robert S. Kerr (*Environmental Protection Agency Laboratory Standard Operating Procedure*).
9. "LUFT" refers to the state of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.
10. *International Journal of Environmental Analytical Chemistry*, Volume 36, pp. 249-257, "Dissolved Oxygen and Methane in Water by a Gas Chromatography Headspace Equilibration Technique," by D. H. Kampbell, J. T. Wilson, and S. A. Vandegrift.